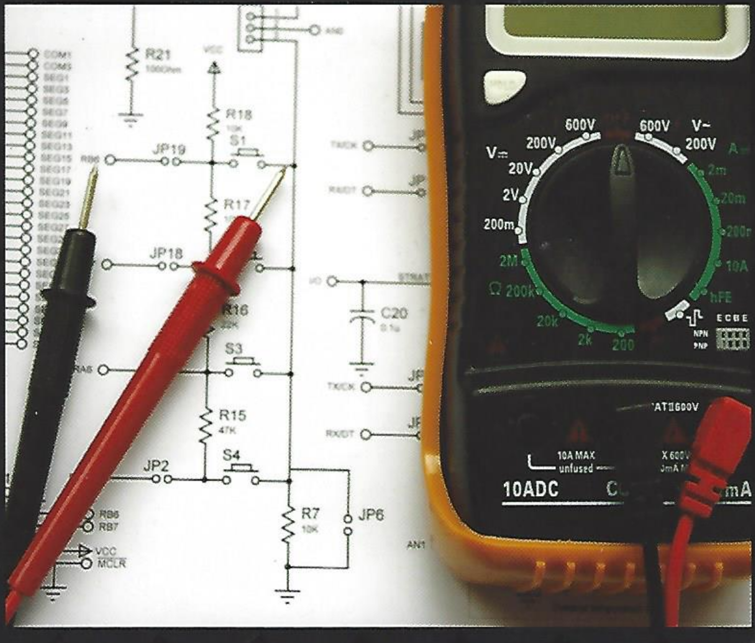
work smarter ...

AUTO TECH

Technical Training Manual

Body Electrical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- CAN network test procedures
- Understand wiring diagrams
- Correct usage of test equipment
- Explore common problems and technical tips

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Body Electrical

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Body Electrical 1
  Look for these symbols throughout the manual 1
Introduction 3
Wiring Diagrams 5
  Schematic Wiring Diagrams 6
    Advantages 6
    Disadvantages 6
  Routing Diagrams 7
    Advantages 7
    Disadvantages 7
  Component Wiring Diagrams 8
    Advantages 8
    Disadvantages 8
  System Wiring Diagrams 9
    Advantages 9
    Disadvantages 9
Essential Systems 11
  Batteries 11
    Wet Cell 11
    Gel Cell 11
    AGM (Absorbed Glass Matt) 11
    State of Charge (SoC) 12
    Battery Testing 13
    Battery Charging 15
  Charging Systems 17
    Traditional Charging Systems: 17
    ECU Controlled Charging Systems 17
  Ground Circuits 19
    Case Study 19
  Ground Circuits continued 32
Data Networking and the OBD Connector 33
    OBD Connector Designation 36
    CAN BUS Testing 41
    CAN BUS Testing 42
    Ford FG Falcon 44
    Holden VE series 46
In practical terms... 49
  Integrated and Hidden Relays 49
    Nissan Intelligent Power Distribution Module - Engine Room (IPDM-E/R) 51
    Holden VZ Commodore – BCM 53
    Toyota – Integration Relay 54
  Heating, Ventilation and Air Conditioning (HVAC) 55
    Holden VE Series I – Actuators 55
  Electronic Power Steering (EPS) 58
    EPS Configurations/Drive Systems 58
    EPS Torsion Bar and Torque Sensor 61
    EPS Control Module 63
    EPS Current Draw Inspections 64
  Electronic Parking Brake (EPB) 71
    Cable Actuated 71
    Electronic Brake Calliper 72
    2012 Subaru Outback – EPB Investigations 74

LOOK FOR THESE SYMBOLS THROUGHOUT THE MANUAL

Note: *Indicates a point of interest*

Caution: *Indicates the risk of minor injury, special procedure or possible damage to a component*

Warning: *Indicates the risk of serious or life threatening injury*

Introduction

Electrical technology has changed the driver's expectations of comfort and reliability, and it is becoming common-place for just about every accessory fitted to today's car to be controlled electronically.

Examples of the evolving nature of these systems are:

- Traditional mechanical devices such as HVAC, brake boosters and hand brakes that have evolved into electronically controlled systems.
- Once standalone electrical devices like power windows and central locking now each have their own diagnostic module and share data on a CAN network.
- Completely new electronic technologies are being invented and added by manufacturers every day.

> *"One thing is clear… the future of cars will involve more and more electronic systems, and the challenge to business will be keeping up with technology."*

Never before has it been more prudent to not only understand how each system operates and the sensors involved, but to go back to basics and realise that the body ground point or charging system that was 'good enough' on a vehicle built 10 years ago, could in fact be the cause of the impossible-to-diagnose fault of an ultra-sensitive body or engine control system today.

Because of the growth of electrical technology, due mainly to comfort improvements becoming more affordable, the need for a technician to keep up to date with tools, testing procedures and diagnostic strategies for when these technologies fail is increasing. Small mistakes or missed clues at an early stage of the diagnostic process will cost time and money for the workshop in the long run.

Wiring Diagrams

Wiring Diagrams provide invaluable information about a components position in any electrical system, this information is rarely matched in any text descriptions.

> *"This means that unless you understand the wiring diagram, you are only working with half of the available information!"*

To use wiring diagrams accurately you must understand the type of diagram you are presented with, as this determines its intention/accuracy. Most manufacturers provide a selection of different wiring diagram types. Each has their intended uses, benefits and also limitations.

Wiring Diagrams can be roughly categorised into the following four types:

- Schematic
- Routing
- Component
- System

SCHEMATIC WIRING DIAGRAMS

Schematic diagrams give an outline of the system architecture but do not hold enough information for accurate diagnostic purposes.

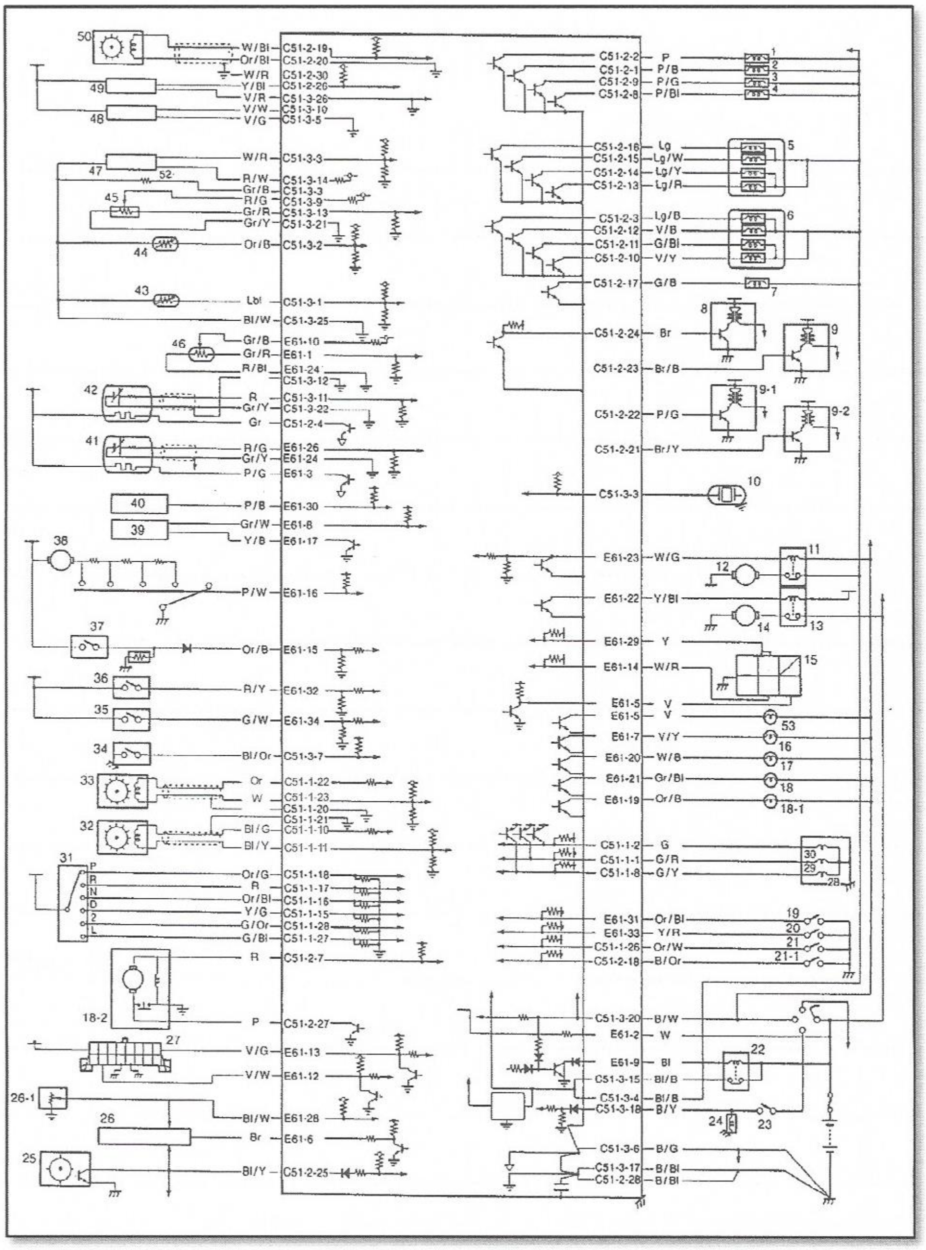
Advantages

Schematic diagrams provide an overview of the system architecture. In the example (*see Diagram 1*) below items 8, 9, 9.1 & 9.2 are ignition coils and as this vehicle has a 4 cylinder engine we can interpolate that the vehicle is fitted with a Coil On Plug (COP) ignition system.

Disadvantages

Commonly schematic diagrams omit:

- Power circuits
- Ground circuits
- Some/all of the fuses
- Auxiliary circuits such as A/C and Cooling Fan (in engine control diagrams)



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G/Bl
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C51-2-19
C51-2-20
C51-2-30
C51-2-26
C51-3-26
C51-3-10
C51-3-5
C51-3-3
C51-3-14
C51-3-9
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E61-10
E61-1
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C51-3-12
C51-3-11
C51-3-22
C51-2-4
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E61-34
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C51-2-2
C51-2-1
C51-2-9
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P
P/B
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C51-2-13
Lg
Lg/W
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Lg/R
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C51-2-3
C51-2-12
C51-2-11
C51-2-10
Lg/B
V/B
G/Bl
V/Y
6
C51-2-17
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7
8
C51-2-24
Br
9
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Br/B
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E61-29
Y
E61-14
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15
E61-5
V
E61-5
V
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E61-7
V/Y
16
E61-20
W/B
17
E61-21
Gr/Bl
18
E61-19
Or/B
18-1
C51-1-2
G
C51-1-1
G/R
C51-1-8
G/Y
30
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E61-31
Or/Bl
E61-33
Y/R
C51-1-26
Or/W
C51-2-18
B/Or
19
20
21
21-1
C51-3-20
B/W
E61-2
W
E61-9
Bl
C51-3-15
Bl/B
C51-3-4
Bl/B
C51-3-18
B/Y
22
24
23
C51-3-6
B/G
C51-3-17
B/Bl
C51-2-28
B/Bl

Diagram 1: Typical Schematic Wiring Diagram (Image source: Suzuki)

ROUTING DIAGRAMS

Routing (also called harness layout) diagrams show where wiring looms and connectors are situated. Manufactures typically provide routing diagrams for ALL wiring looms. Some manufacturers also provide alternative versions of each routing diagram for:

- Component Connectors
- Harness Connectors
- Junction Connectors and Splices
- Ground points

Advantages

Routing diagrams can be helpful in the absence of component location information. All connectors are typically identified with an alpha/numerical code. These codes are usually provided in the diagnostic information as well as in the detailed wiring diagrams. By cross referencing the connector codes to the routing diagram (*see Diagram 2*), the location of the connector (and therefore the component) can be easily identified.

Disadvantages

No diagnostic information.

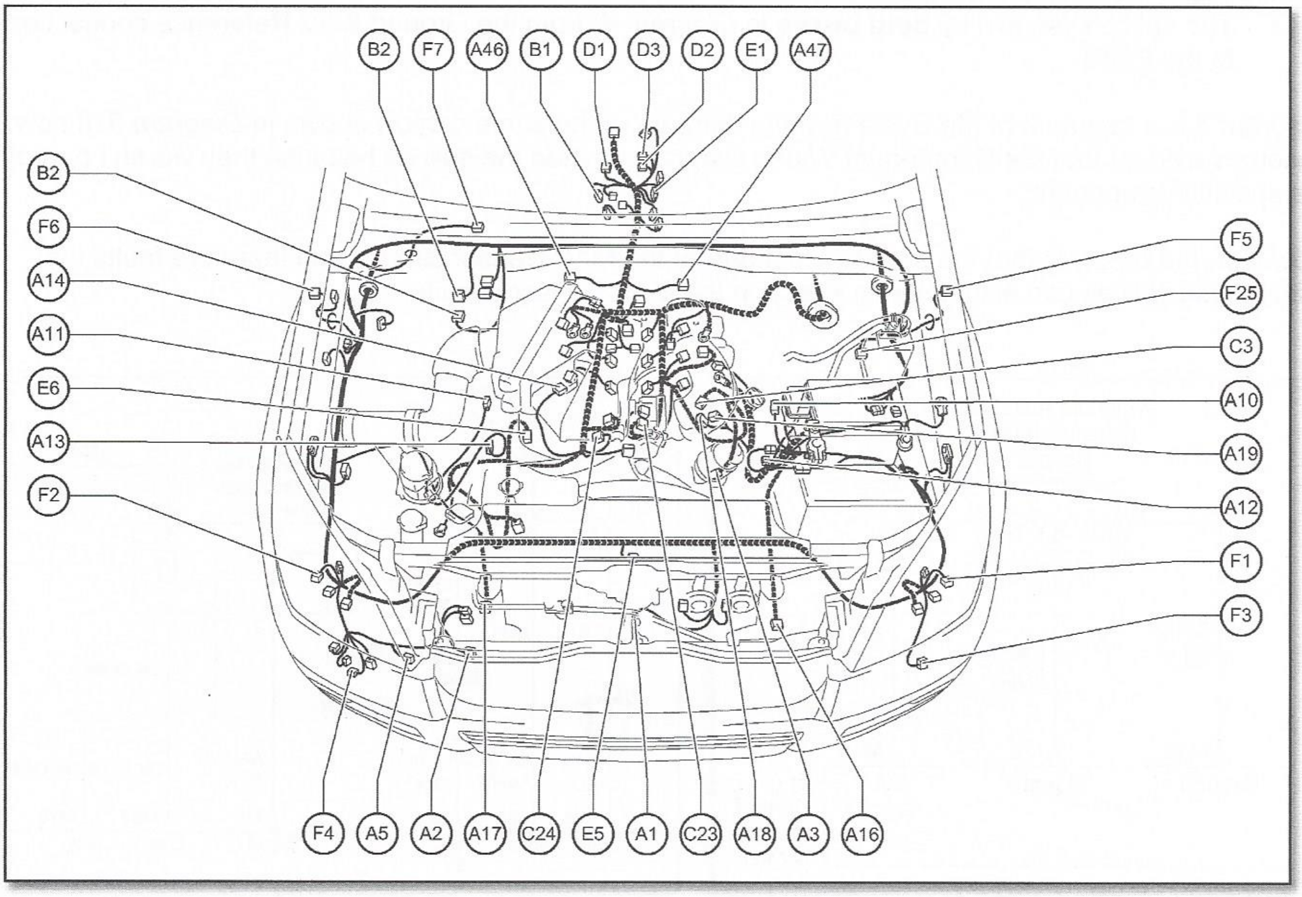


Diagram 2: Typical Routing Diagram (Image source: Toyota)

COMPONENT WIRING DIAGRAMS

Individual component diagrams can be helpful in understanding the actual component as they usually include diagrammatic information about the internal workings of a component.

Advantages

The obvious details:

- Components Names
- Connector and Pin numbers
- Wiring colours
- ECM Signal form

What else does this example diagram tell us?

- Internal characteristics of the component
- The MAP Sensor pins are in the same connector (dashed line between pins)
- All of the MAP Sensor electrical circuits are shown (solid outline of component)
- There are more terminals/circuits to the ECM (dashed outline of component)

Disadvantages

What doesn't the example diagram tell us?

- The splice's (shown by **bold boxes** in *Diagram 4*) from the Ground & 5V Reference connections to the EGR!

Diagram 4 is a segment of the System wiring diagram of the same vehicle shown in *Diagram 3*. It now becomes evident that the Component Wiring Diagram omitted the splices because they weren't part of the specific component.

However, the reality is that the splices are a part of the MAP Sensor circuits and therefore faults that affect those splices can also have an effect on the MAP Sensor circuits.

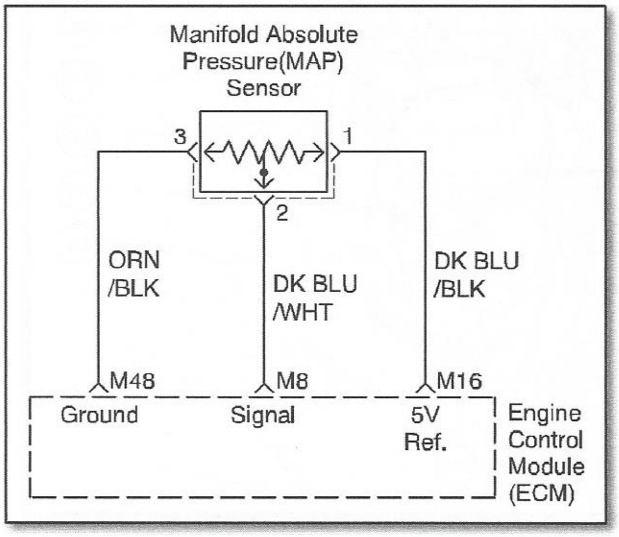

Manifold Absolute Pressure(MAP) Sensor
3
1
2
ORN /BLK
DK BLU /WHT
DK BLU /BLK
M48
M8
M16
Ground
Signal
5V Ref.
Engine Control Module (ECM)

Diagram 3:
Typical Component Wiring Diagram
(Image source: GM/Holden)

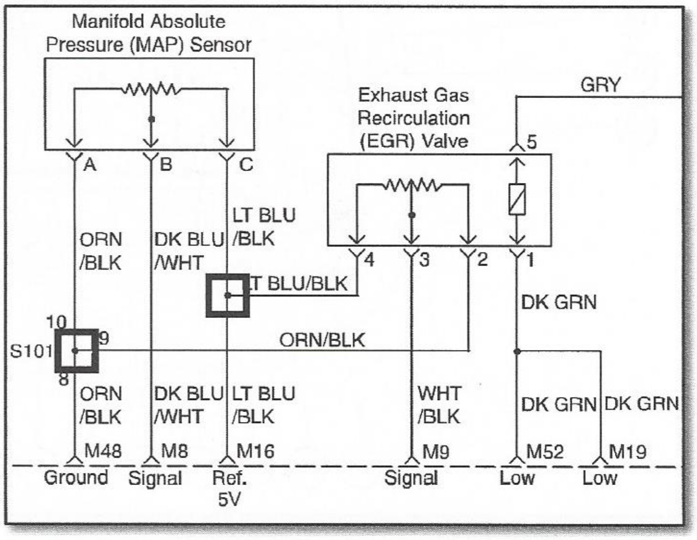

Manifold Absolute Pressure (MAP) Sensor
A
B
C
Exhaust Gas Recirculation (EGR) Valve
GRY
5
4
3
2
1
ORN /BLK
DK BLU /WHT
LT BLU /BLK
T BLU/BLK
DK GRN
10
S101
9
8
ORN/BLK
ORN /BLK
DK BLU /WHT
LT BLU /BLK
WHT /BLK
DK GRN
DK GRN
M48
M8
M16
M9
M52
M19
Ground
Signal
Ref. 5V
Signal
Low
Low

Diagram 4:
Detail from System Wiring Diagram
(Image source: GM/Holden)

SYSTEM WIRING DIAGRAMS

Full system wiring diagrams provide comprehensive system coverage. The layout of these varies between a series of segmented diagrams (as shown in *Diagram 6*) and a single gatefold diagram (as shown in *Diagram 5*).

Advantages

Highly inclusive
These should be used for diagnostic work wherever possible.

Disadvantages

Misdiagnosis can occur when circuits in a wiring diagram are misread. This can prove to be particularly difficult the component in question has a circuit that stretches across 5 or more pages.

Tip: *Using a highlighter to identify circuits improves clarity and reduces the possibility of costly mistakes.*

Another disadvantage of the full System Wiring Diagram is that not all manufacturers provide them. In these circumstances it is usually sufficient to use a combination of schematic and component diagrams collectively.

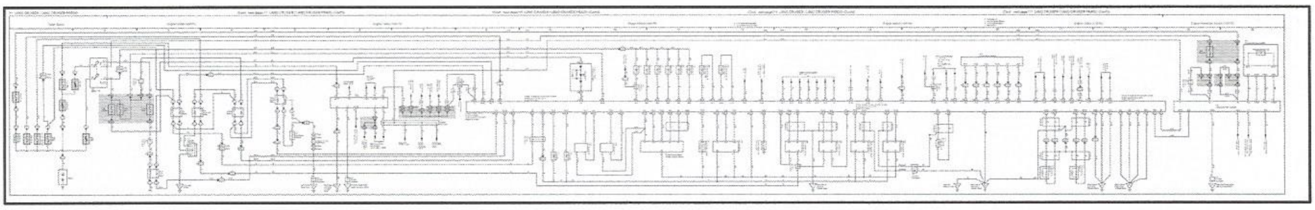


Diagram 5: Typical broadsheet System Wiring Diagram (Image source: Toyota)

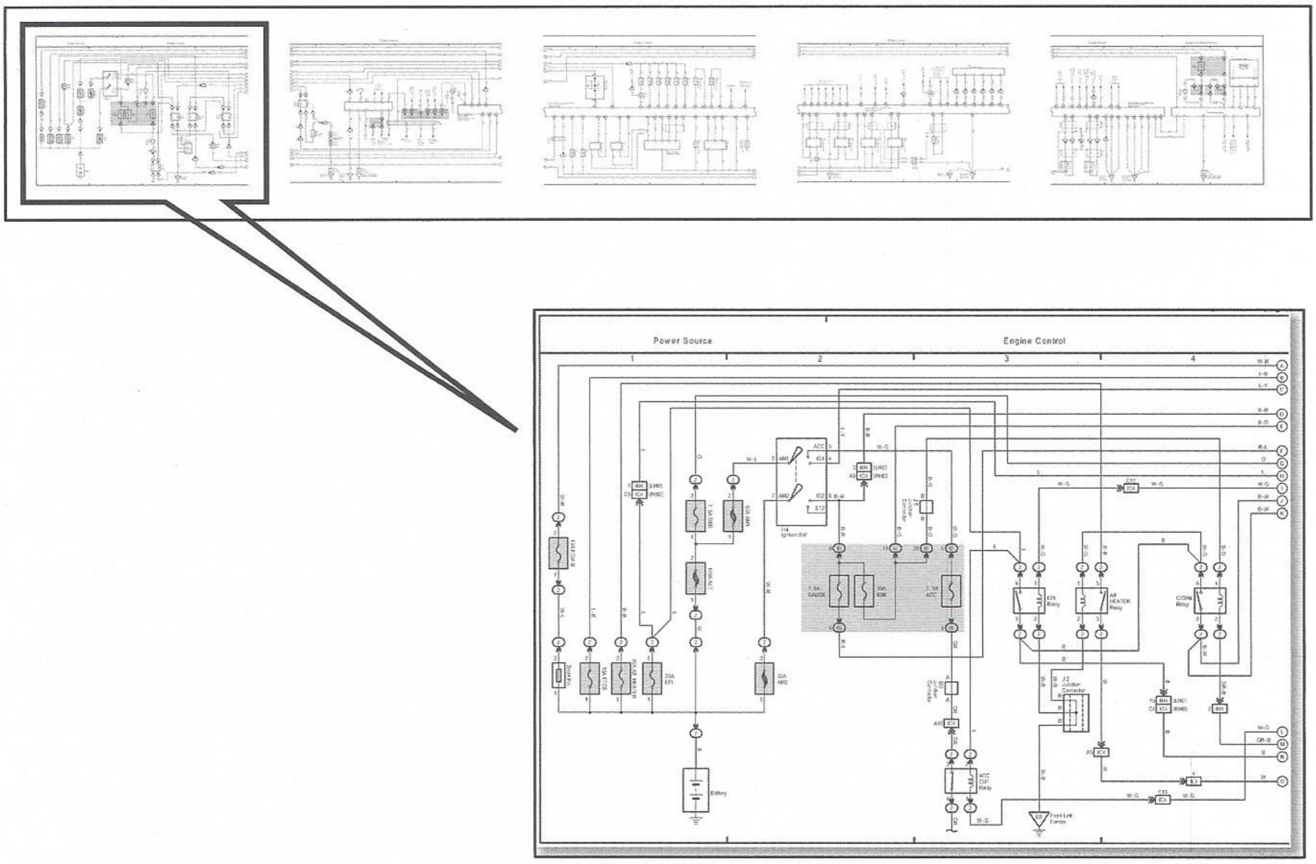


Diagram 6: Typical sectioned System Wiring Diagram (Image source: Toyota)

Essential Systems

BATTERIES

If a vehicles battery is NOT fully serviceable, then the components connected to that battery cannot be expected function normally. Most ECU's are programmed to protect themselves from excessive voltage fluctuation, it is imperative that the battery is serviceable.

There are essentially 3 main types of batteries used in the mainstream market:

- Wet Cell – these include Lead/Acid, Lead/Calcium and Calcium/Calcium variations.
- Gel Cell – where the fluid has a silica additive that converts it into a Gel.
- AGM (Absorbed Glass Matt) – AGM batteries use a fibre-glass matt (sponge) to hold the electrolyte in suspension.

Wet Cell

Wet Cell batteries are the most commonly found battery used in automotive vehicles. They are relatively inexpensive to make and are not adversely affected by the intermittent high output need to power a starter motor. However, cell depletion does occur if they are excessively discharged (deep-cycled). A Wet Cell battery will provide the longest service life when kept above 95% SOC (State of Charge).

Gel Cell

Gel Cell batteries acquire their name from the silica additive that is used to convert the electrolyte into a Gel. The Gel Cell batteries heavier plates and gel electrolyte suspension make it a suitable deep cycle battery and although it is capable of operating a starter motor the gel electrolyte suspension is less affective at dispersing heat than Wet Cell batteries and therefore reduce their service life.

AGM (Absorbed Glass Matt)

AGM batteries use a fibre-glass matt (sponge) to hold the electrolyte in suspension. While they are technically a Wet Cell battery their function is better described as a Hybrid Battery (functioning with both Shallow & Deep Cycle characteristics). While their physical size needs to be larger than a wet cell battery of the same CCA, an AGM battery will not be adversely affected by regular high current use (engine starting, particularly start/stop systems) and can safely be used to 50% of it discharge rate (Wet-Cell batteries perform best within a 2 to 5% discharge rate). This makes AGM batteries a perfect option for modern vehicles with high electrical loads.

The cost of making an AGM battery is comparable to that of a Gel Cell and because of their hybrid functionality they are now replacing Gel Cell batteries in most automotive vehicles.

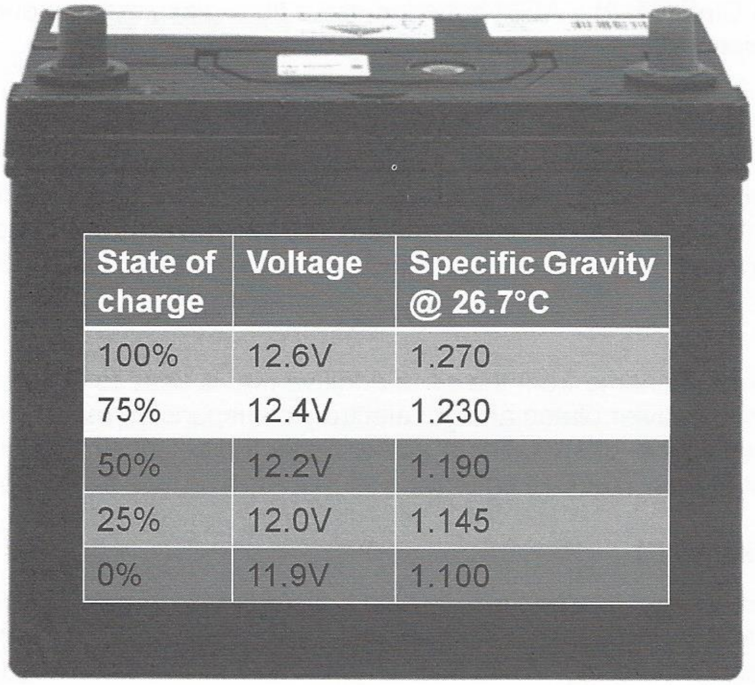
BATTERIES continued...

State of Charge (SoC)

A batteries State of Charge (SoC) is one of the most ill understood principles. It is a common response when queried by Tech-Help about the condition of a battery to hear:

> *"...yes, I've tested the battery and it is fine. It has about 12.2 Volts"*

As shown on *Table 1* below, at 12.2 Volts a battery is at 50% SoC and is considered unserviceable.



State of charge	Voltage	Specific Gravity @ 26.7°C
100%	12.6V	1.270
75%	12.4V	1.230
50%	12.2V	1.190
25%	12.0V	1.145
0%	11.9V	1.100

Table 1: Battery State of Charge (SoC) matrix

Note: *The SoC figures provided in the table above are at 26.7°C*

- *For every 5.5°C above add 0.004SG*
- *For every 5.5°C below subtract 0.004SG*

BATTERIES continued...

Battery Testing

Battery testing can be done in two ways:

- Capacity/Load Test
- Conductance Test

Capacity/Load Test

While the Capacity/Load Test provides the most accurate analysis of the peak load output, the test has a number of downsides. Firstly, you need to know specific details about the battery and use a cross reference chart to calculate the test rate. Secondly, prior to carrying out the Capacity/Load Test you must also test the Specific Gravity (SG) of each cell and test the Open Circuit Voltage. Thirdly, If the battery is not at 75% charge (1.230 SG and 12.4 V) or greater it must be charged before the test is carried out. Lastly, this test is only suitable for traditional lead/acid wet cell batteries.

Capacity/Load Test Procedure

Step	Procedure	Result	Next
1	Test Open Circuit Voltage	>12.4V <12.4V	Step 2 Step 3
2	Test Specific Gravity (SG) of each cell	>1.230SG <1.230SG	Step 5 Step 3
3	Charge Battery then remove surface charge *(see note below)*		Step 4
4	Repeat Steps 1 & 2	Pass Fail	Step 5 Replace Battery
5	Carry out Heavy Load Test and apply temperature correction	>9.6V <9.6V	Battery good – Step 6 Replace Battery
6	Test for Parasitic Load	<50mA@30mins >50mA@30mins	Step 7 Isolate load – Step 7
7	Carry out Voltage Drop tests between each clamp and post with engine cranking	0.0V >0.0V	Job completed Clean/Replace terminal

Table 2: Capacity/Load Test Procedure

Note: *There are 3 ways to remove Surface Charge*

1. *Apply a 200A load test for 10 seconds*
2. *High beams ON for 3 to 5 minutes (3mins = Compact Car / 5mins = 4x4)*
3. *Leave battery static for 24hrs*

BATTERIES continued...

Conductance Test

The Conductance Test is sometimes referred to as an Electronic Test and while it is not quite as accurate at testing the peak load condition of the battery, its reduced input by the technician reduces 'human error' and its ability to test batteries at any charge state (SoC) makes these tests far more practical.

The Conductance Test works by applying a signal (AC current) across the battery and then measuring the response. Depending on the tester, this test can be suitable for all types of automotive batteries and many testers include a printer for warranty claims and customer reassurance.

Conductance Test Procedure

Step	Procedure	Result	Next
1	Carry out Conductance Test	Pass Fail	Step 2 Replace Battery
2	Test for Parasitic Load	<50mA@30mins >50mA@30mins	Step 3 Isolate load > Step 3
3	Carry out Voltage Drop tests between each clamp and post with engine cranking	0.0V >0.0V	Job completed Clean or Replace terminals

Table 3: Conductance Test Procedure

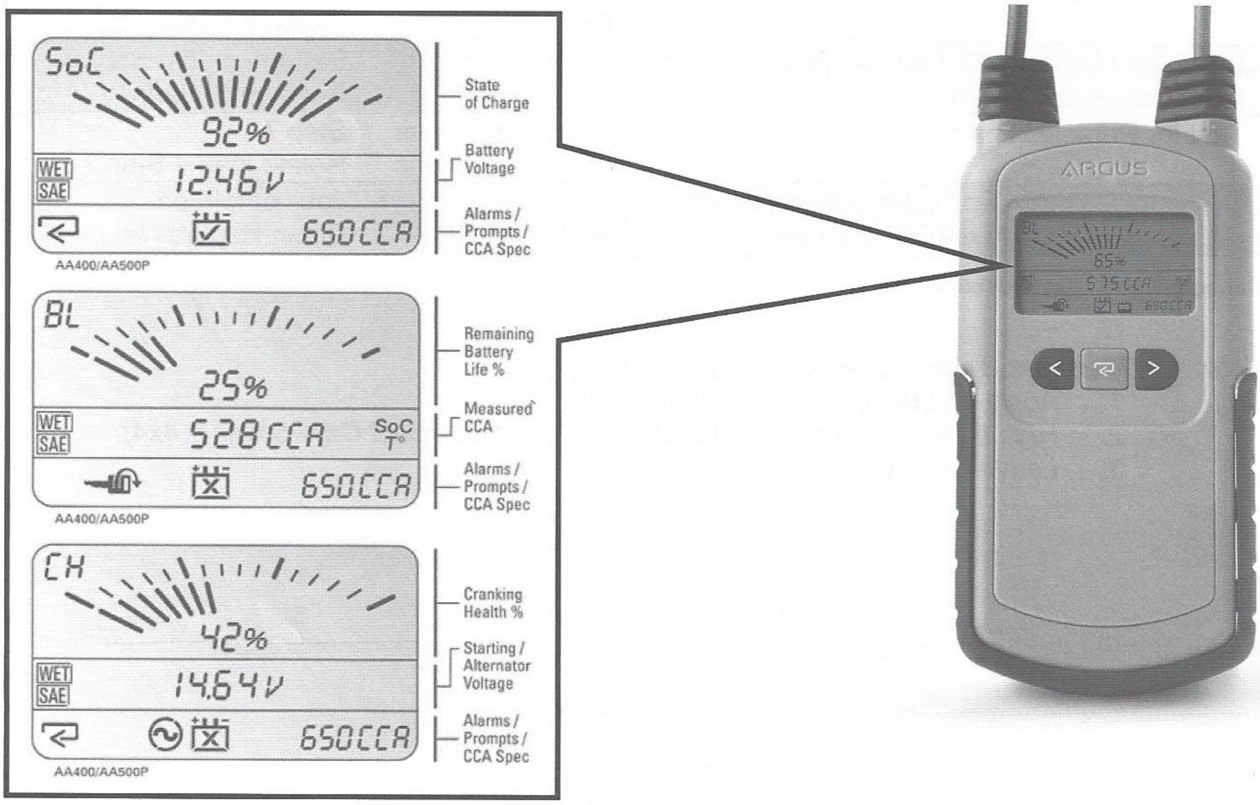

SoC
92%
WET
SAE
12.46V
650CCA
AA400/AA500P
State of Charge
Battery Voltage
Alarms / Prompts / CCA Spec
BL
25%
WET
SAE
528CCA
SoC
T°
650CCA
AA400/AA500P
Remaining Battery Life %
Measured CCA
Alarms / Prompts / CCA Spec
CH
42%
WET
SAE
14.64V
650CCA
AA400/AA500P
Cranking Health %
Starting / Alternator Voltage
Alarms / Prompts / CCA Spec
ARGUS
BL
65%
575CCA
650CCA
<
>

Figure 1: Argus AA500-PWP Conductance Tester (image source: Argus)

Note: *Some Conductance Testers also include Starting and Charging System testing capabilities.*

BATTERIES continued...

Battery Charging

Regardless of the Battery Charger they all work by applying an electric current which reverses the chemical reaction in the Battery. For a lead/acid battery, it is considered fully charged when there has been no change in the Specific Gravity (SG) for one hour.

There are two types of battery charges:

- Manual
- Automatic

Manual Chargers

Manual chargers are sufficient at replenishing the charge in a battery. However, in recent years automatic chargers have developed dramatically and now provide benefits that cannot be achieved with a manual charger. If charging with a manual charger, ensure that the charge rate is correct for the size of the battery. Charge rates are shown in *Table 4* below.

State of Charge (SoC)	**0%**		**25%**		**50%**		**75%**	
Charge Rate - Amps	**5A**	**10A**	**5A**	**10A**	**5A**	**10A**	**5A**	**10A**
50RC	300	150	225	180	150	75	75	35
60RC	360	180	270	135	180	90	90	45
70RC	420	210	315	135	210	105	105	50
80RC	480	240	360	180	240	120	120	60
90RC	540	270	405	200	270	135	135	65
100RC	600	300	450	225	300	150	150	75
110RC	660	330	495	240	330	165	165	80
120RC	720	360	540	270	360	180	180	90
Reserve Capacity (RC)	**Charging Period (minutes)**							

Table 4: Manual charge rates for lead acid batteries

Caution: *If the Reserve Capacity is unknown, charge at 5A rate and test the Specific Gravity (SG) every hour. Charge until there is no change in SG for 1 hour.*

Automatic Chargers

Automatic chargers are the preferred method for charging batteries. There is little to no input required from the technician and the multi-stage chargers advance automatically once the battery reaches milestones. For AGM batteries, the use of a suitable automatic charger is the only method. *Diagram 7* below describes the steps of a quality multi-stage charger.

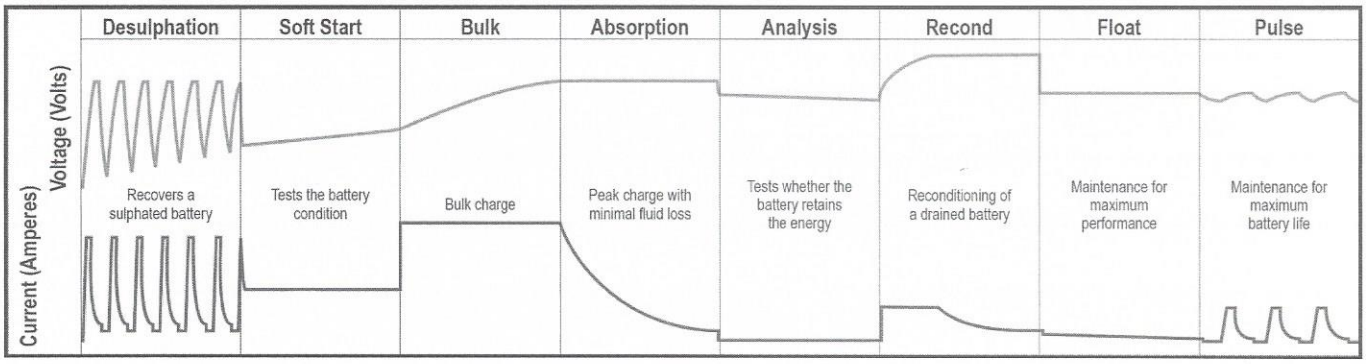


Diagram 7: Automatic charging cycles (Image source: CTEK)

CHARGING SYSTEMS

Now that we understand the importance of maintaining a serviceable battery it is essential to ensure that the charging system is functioning correctly.

Traditional Charging Systems:

Traditional Charging Systems should be checked for the correct charge rate. If a vehicle has presents with electrical related faults, the Alternator should be checked under No-Load & Loaded (High-Beam ON) with the engine idling. Both should have an output of 12.8 to 14.8 Volts.

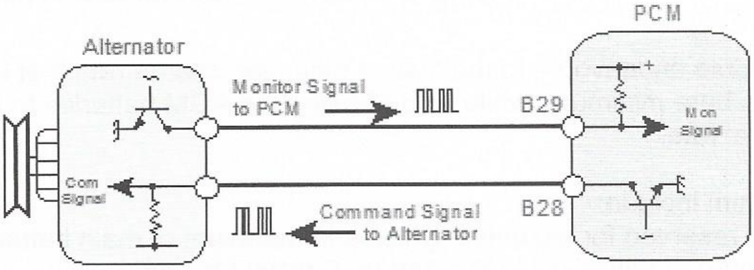
Caution: *Vehicles fitted with a Calcium Battery as Original Equipment (OE) can have charge rate voltages as high as 17.0 Volts! Ensure that if the Battery is being replaced it is suitable for the vehicles Charging System.*

ECU Controlled Charging Systems

ECU controlled charging systems can usually be accurately checked with a compatible Scan Tool. The charge rate of these vehicles varies upon many factors, so a typical alternator output test will not give an accurate indication of alternator condition.

Caution: *Some vehicles are easy to see that they are using a Smart Charging system. Those using a "Black Box" on the Battery Terminal are an easy pick. However, others are not so obvious. If you are unsure about the type of charging system that is fitted to a particular vehicle you should refer to that vehicles specific data.*

Some vehicles such as the VE Commodore hide the Battery Load Sensor in the spare wheel well that is not so easy to find. Another variation is the FG Falcon (see *Diagram 8*) that doesn't use a battery sensor or any other additional sensors for that matter, it estimates (infers) Battery Temp based on Cylinder Head Temp at Low Speeds and on equation based upon Intake Air Temp and Vehicle Speed while at higher speeds.



Ford Falcon FG Series I6 Altemator Monitor and Command Circuits

Diagram 8: FG Falcon charging system

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CHARGING SYSTEMS continued...

Another more complex ECU controlled charging system can be found in the W211 series Mercedes Benz E-Class range (see *Diagram 9*).

The system consists of:

- 2 x AGM Batteries (Main in boot & Auxiliary in RHR corner of the Engine Bay)
- A dedicated Battery Control Module on the secondary CAN BUS network
- Alternator
- Changeover Relay (controlling Aux Battery)
- Various fuses

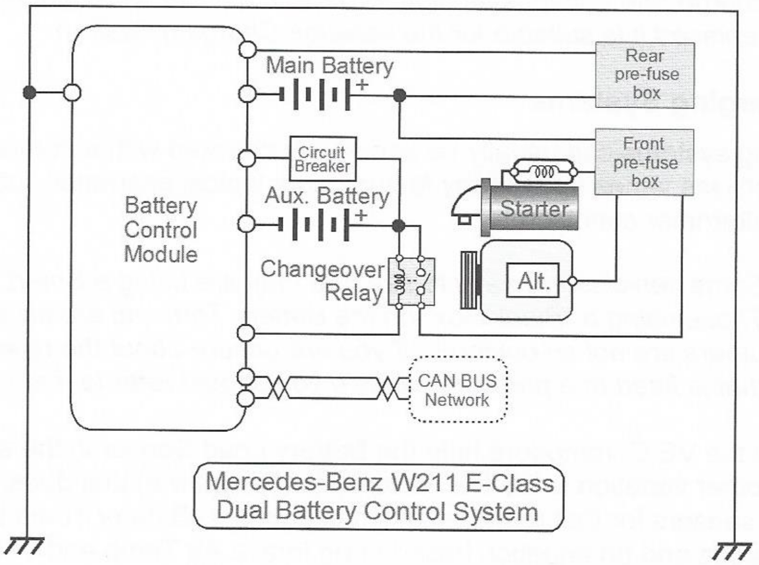

Main Battery
+
Rear pre-fuse box
Circuit Breaker
Front pre-fuse box
Battery Control Module
Aux. Battery
+
Starter
Changeover Relay
Alt.
CAN BUS Network
Mercedes-Benz W211 E-Class
Dual Battery Control System

Diagram 9: Mercedes Benz E-Class (W211) charging system

The Battery Control Module endeavours to maintain a balanced charge rate that keeps engine load and therefore emissions to a bare minimum, while also allowing the AGM batteries to be used and replenished at an optimal rate.

Key features of the system include:

- Auxiliary Battery reserved for essential systems in the event of main battery depletion
- Accurate monitoring of batteries via the Battery Control Module
- Optimised charging not only for the AGM Batteries but also for vehicle operating habits to extend Battery Life

GROUND CIRCUITS

Poor ground circuit continuity continues to plague automotive electrical systems. Understanding how to effectively determine if a ground circuit is serviceable is critical for competent diagnosis.

The following pages recount a recent case study that led to the diagnosis and repair of a poor ground circuit and highlights the importance of correct testing procedures.

Note: *It is intentional that such a simple example has been chosen, as it puts focus on the cause rather than the detail. Although simple, the same principles apply to high current ground points such as the battery ground as well as intricate ground points in the most high-tech data networks.*

Case Study

Vehicle: 2006 Toyota Prado GRJ120 4.0L V6

Complaint 1: Intermittent squawking noise from behind the Instrument Cluster, more common while driving at night.

Complaint 2: Fuel level intermittently inaccurate

Condition: Unable to witness either condition with customer.

GROUND CIRCUITS continued...

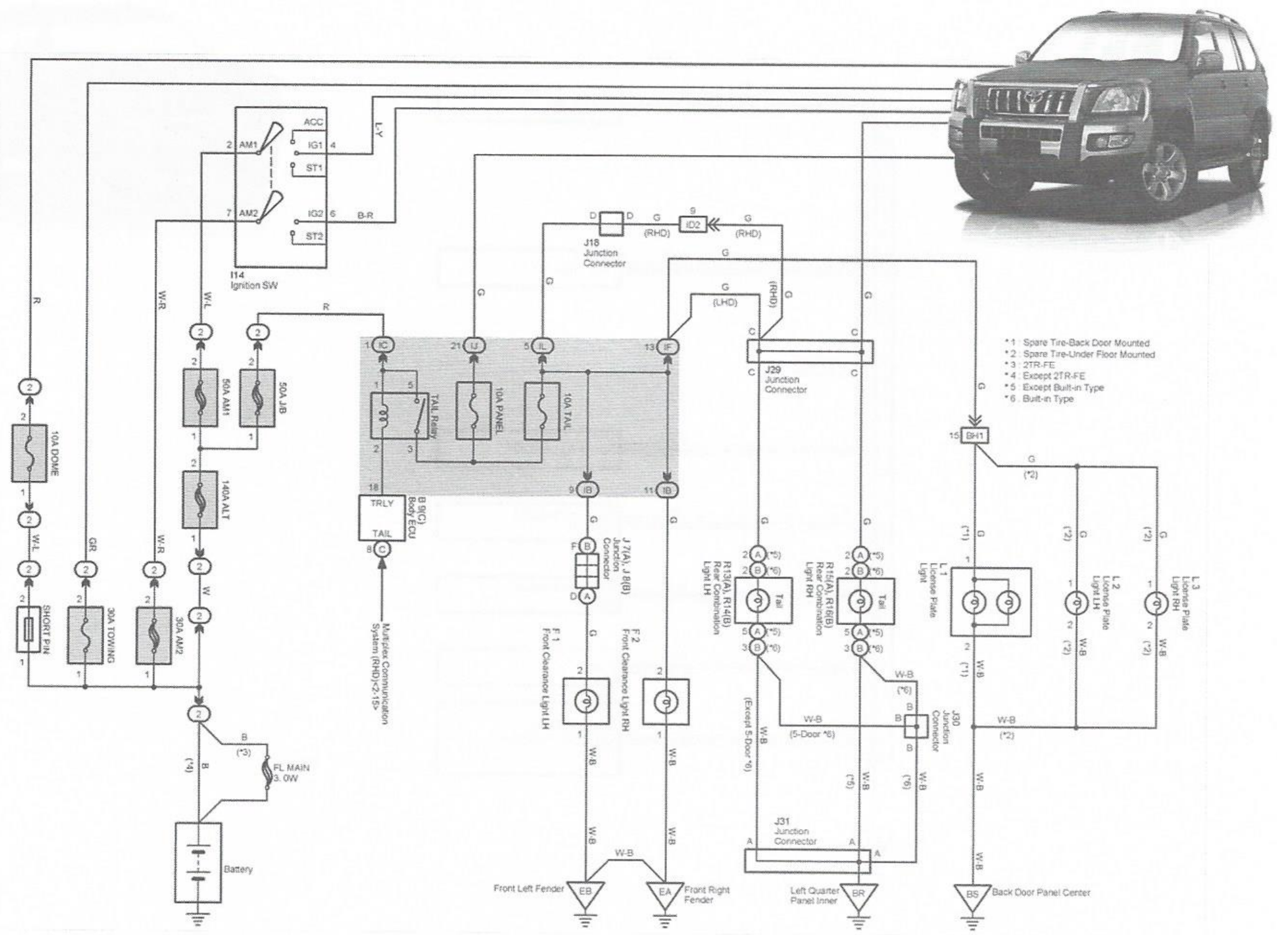
Further Investigation:

After further investigation it was found that with tail, brake and indicator lamps on simultaneously the indicator relay would make an intermittent *"chatter"*.

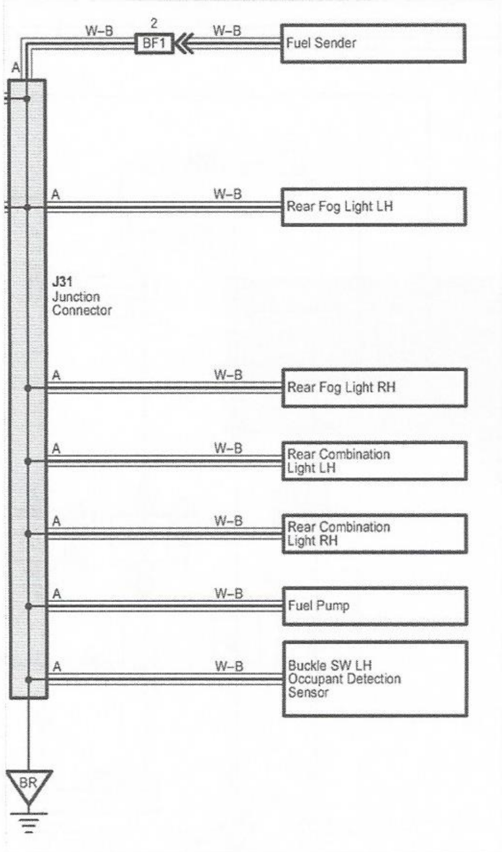
The individual lamps in the LHR assembly also showed signs of *"signalling"*.

No fault could be found with the Fuel Gauge operation

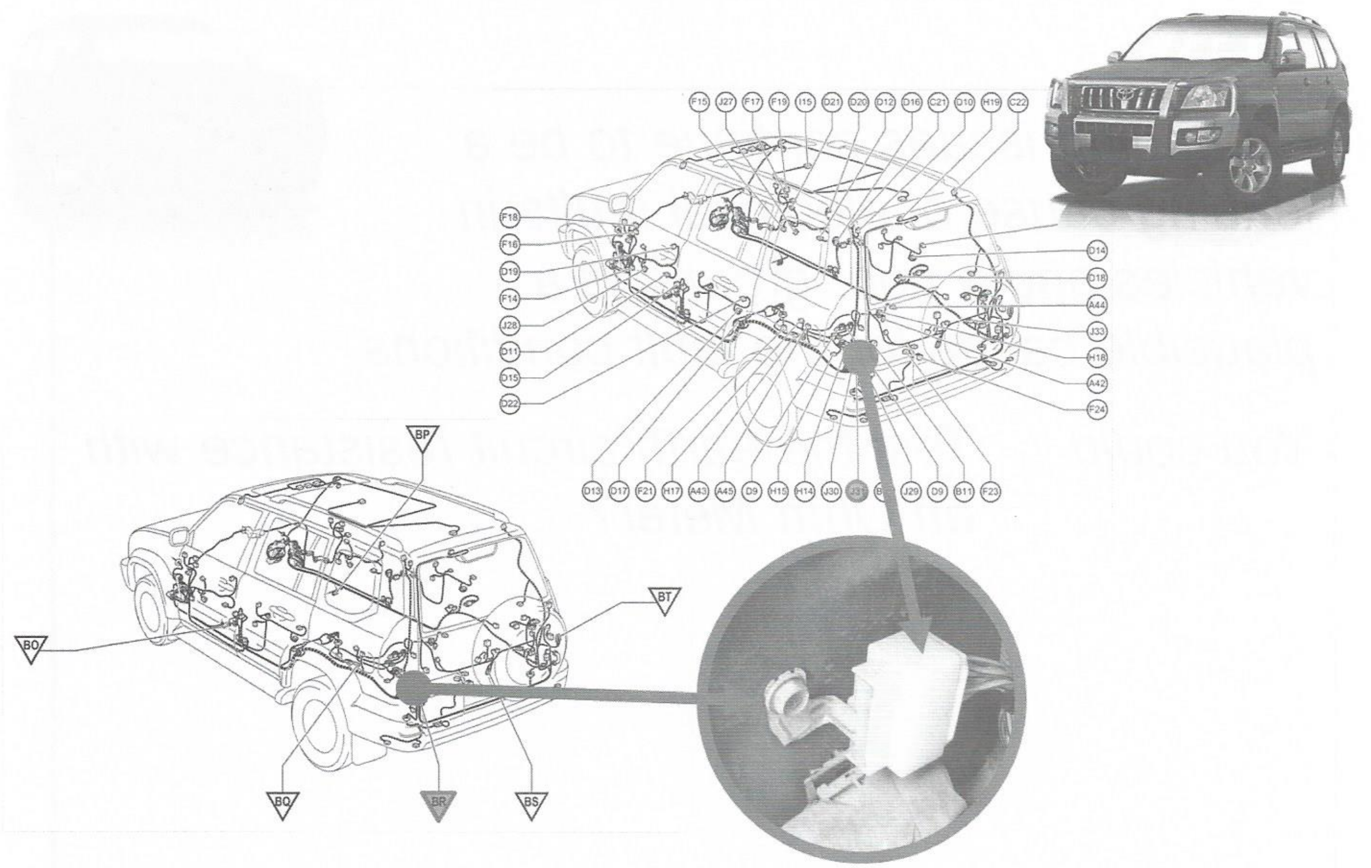
GROUND CIRCUITS continued...


ACC
AM1
IG1
ST1
AM2
IG2
ST2
L-Y
B-R
I14
Ignition SW
R
W-R
W-L
GR
W
B
10A DOME
50A AM1
50A J/B
140A ALT
30A TOWING
30A AM2
SHORT PIN
FL MAIN
3.0W
Battery
(*3)
(*4)
TAIL Relay
10A PANEL
10A TAIL
TRLY
TAIL
B 9(C)
Body ECU
Multiplex Communication System (RHD)<2-15>
J18
Junction Connector
ID2
(RHD)
(LHD)
G
J7(A), J8(B)
Junction Connector
F1
Front Clearance Light LH
F2
Front Clearance Light RH
W-B
J29
Junction Connector
R13(A), R14(B)
Rear Combination Light LH
R15(A), R16(B)
Rear Combination Light RH
Tail
J30
Junction Connector
(5-Door *6)
(Except 5-Door *6)
J31
Junction Connector
BH1
L1
License Plate Light
L2
License Plate Light LH
L3
License Plate Light RH
*1 : Spare Tire-Back Door Mounted
*2 : Spare Tire-Under Floor Mounted
*3 : 2TR-FE
*4 : Except 2TR-FE
*5 : Except Built-in Type
*6 : Built-in Type
Front Left Fender
EB
EA
Front Right Fender
Left Quarter Panel Inner
BR
BS
Back Door Panel Center

GROUND CIRCUITS continued...


W–B
2
BF1
W–B
Fuel Sender
A
A
W–B
Rear Fog Light LH
J31
Junction
Connector
A
W–B
Rear Fog Light RH
A
W–B
Rear Combination
Light LH
A
W–B
Rear Combination
Light RH
A
W–B
Fuel Pump
A
W–B
Buckle SW LH
Occupant Detection
Sensor
BR

GROUND CIRCUITS continued...


F15
J27
F17
F19
I15
D21
D20
D12
D16
C21
D10
H19
C22
F18
F16
D19
F14
J28
D11
D15
D22
D14
D18
A44
J33
H16
A42
F24
D13
D17
F21
H17
A43
A45
D9
H15
H14
J30
J31
J29
D9
B11
F23
BP
BT
BO
BQ
BR
BS

GROUND CIRCUITS continued...

Grounding issues continue to be a leading cause of electrical faults in vehicles and a poor ground is a plausible cause for the fault conditions.

You could... Test the earth circuit resistance with an Ohm Meter?

GROUND CIRCUITS continued...

Or...

You could carry out a Voltage Drop test.

To carry out a Voltage Drop test, you need to measure the ***total*** *voltage drop from the component to the negative battery post* ***while*** *the circuit is under electrical load.*

GROUND CIRCUITS continued...

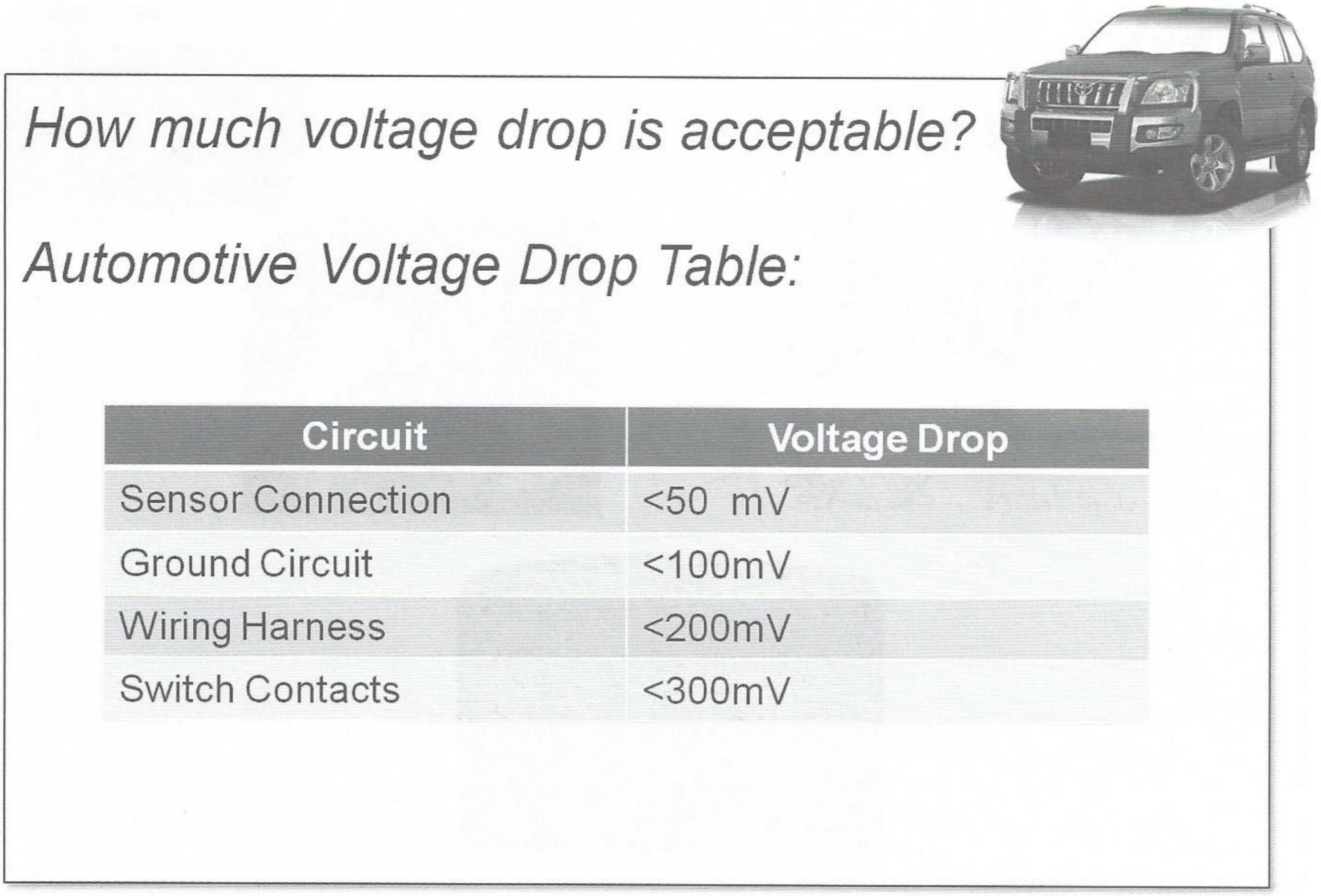
How much voltage drop is acceptable?

Ohm's Law:

V = I x R
I x R = V

So to equate this we need to know:
I – The total Amps drawn by all of the bulbs
R – (pL/A)The conductivity (p) of the wire, it's length (L) and diameter (A)

GROUND CIRCUITS continued...

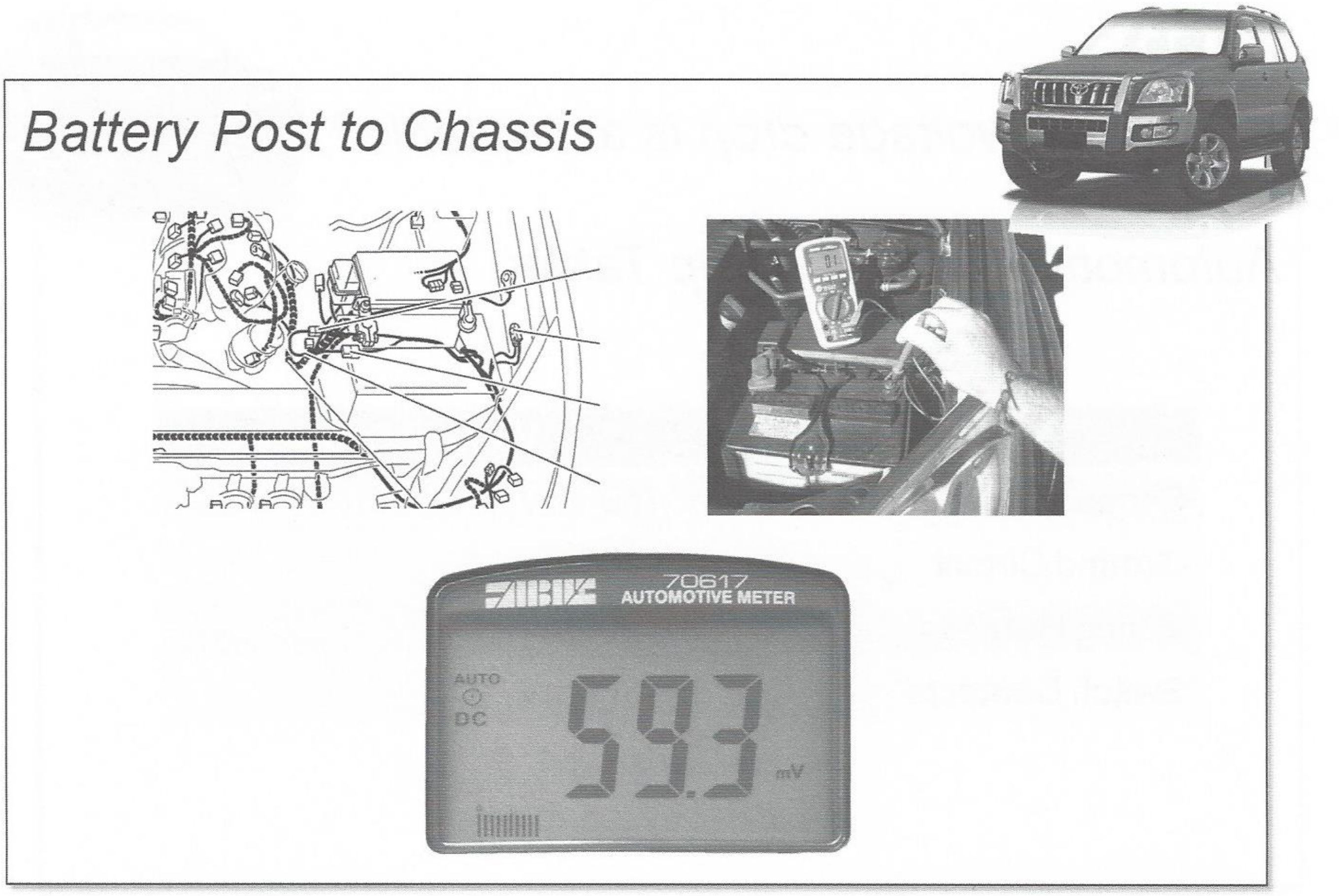


How much voltage drop is acceptable?

Automotive Voltage Drop Table:

Circuit	Voltage Drop
Sensor Connection	<50 mV
Ground Circuit	<100mV
Wiring Harness	<200mV
Switch Contacts	<300mV

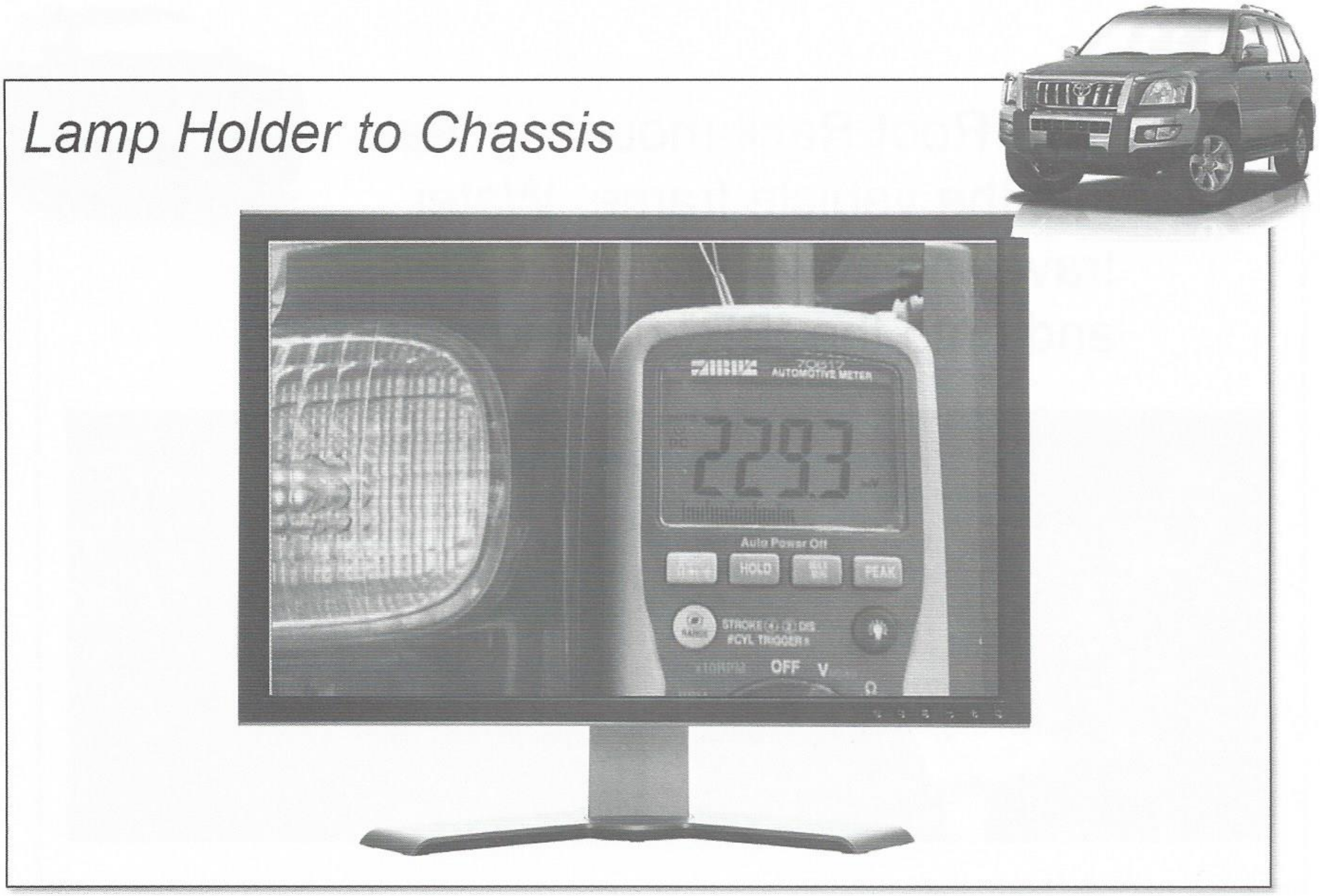
GROUND CIRCUITS continued...



Battery Post to Chassis

70617
AUTOMOTIVE METER
AUTO
DC
59.3
mV

GROUND CIRCUITS continued...

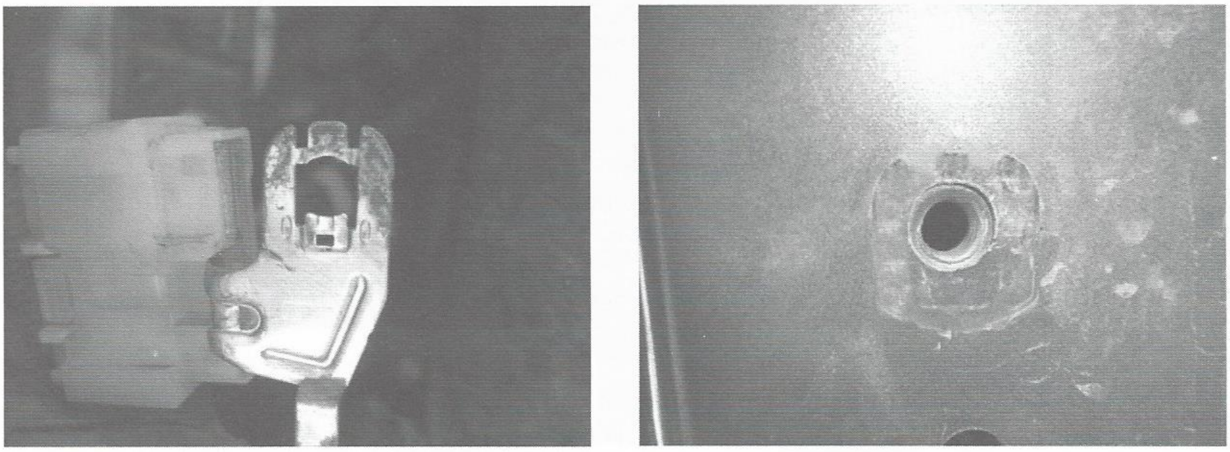


Lamp Holder to Chassis

AUTOMOTIVE METER
229.3
mV
Auto Power Off
HOLD
PEAK
STROKE 4 2 DIS
#CYL TRIGGER
OFF
V
Ω

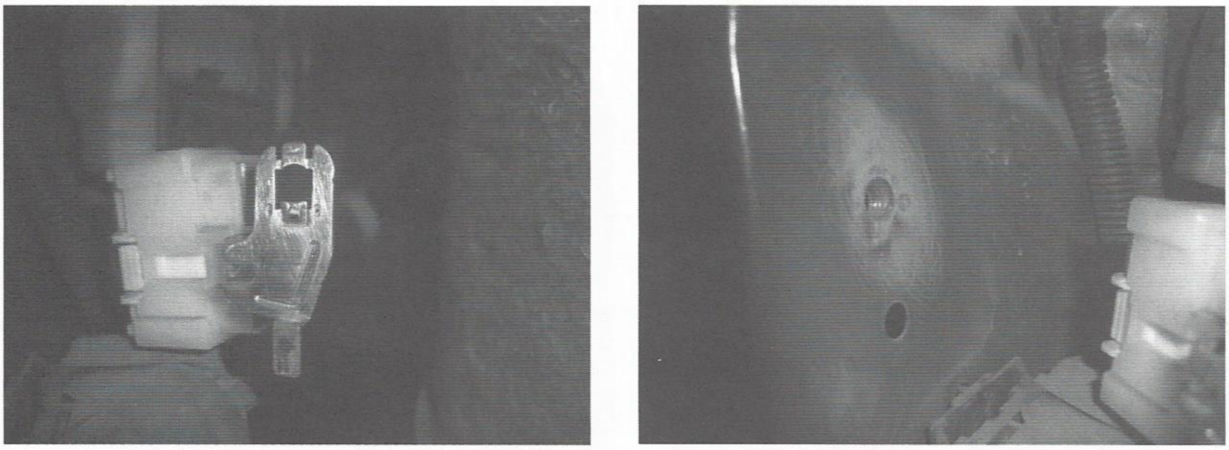
GROUND CIRCUITS continued...

Fault: LHR Roof Rack mounting leak into the vehicle frame. Water travelling down the LHR D-Pillar and onto the "BR" ground point.



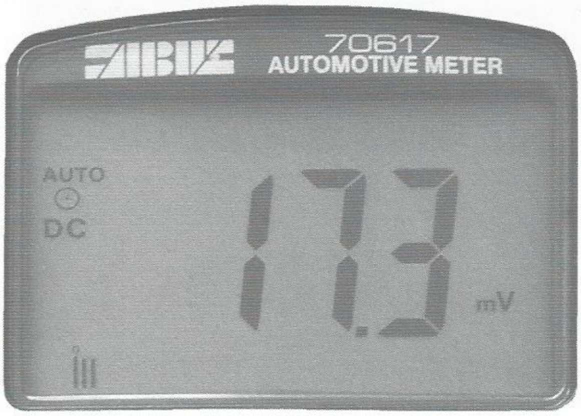
GROUND CIRCUITS continued...

Repair: Clean up both surfaces of the ground point, apply dielectric grease and re-fit



GROUND CIRCUITS continued...

Verification: *Reproduce the fault conditions and check the that the fault is corrected an that the Voltage Drop is now within parameters.*


70617
AUTOMOTIVE METER
AUTO
DC
17.3
mV

Data Networking and the OBD Connector

Since Auto-Tech last ran a clinic based on vehicle electrical systems the architecture of data networks has developed substantially. In many cases these are referred to as CAN BUS however this is only one protocol of many utilised.

Central hubs usually referred to as 'Gateway or Interface Control Modules' are now utilised to tie virtually every system of the vehicle together and translate the data between systems/protocols in a complex network of data sharing. In some networks the 'Gateway' is a dedicated module such as the Audi Q7 pictured (see *Diagram 10* on the following page), while other systems integrate the 'Gateway' into an existing module.
It is imperative to understand the architecture of these networks before undertaking diagnosis.

A very simple example of how data networking has changed vehicle design is the retiring of the Vehicle Speed Sensor and in place the Engine Control Module takes the vehicle speed from the ABS/ESP Control Module via the data network, which is in fact an average of all wheel speed sensors.

Over the following pages we'll unravel the complexity of data networks and show how basic testing can diagnose the most complex of networks.

DATA NETWORKING AND THE OBD CONNECTOR continued...

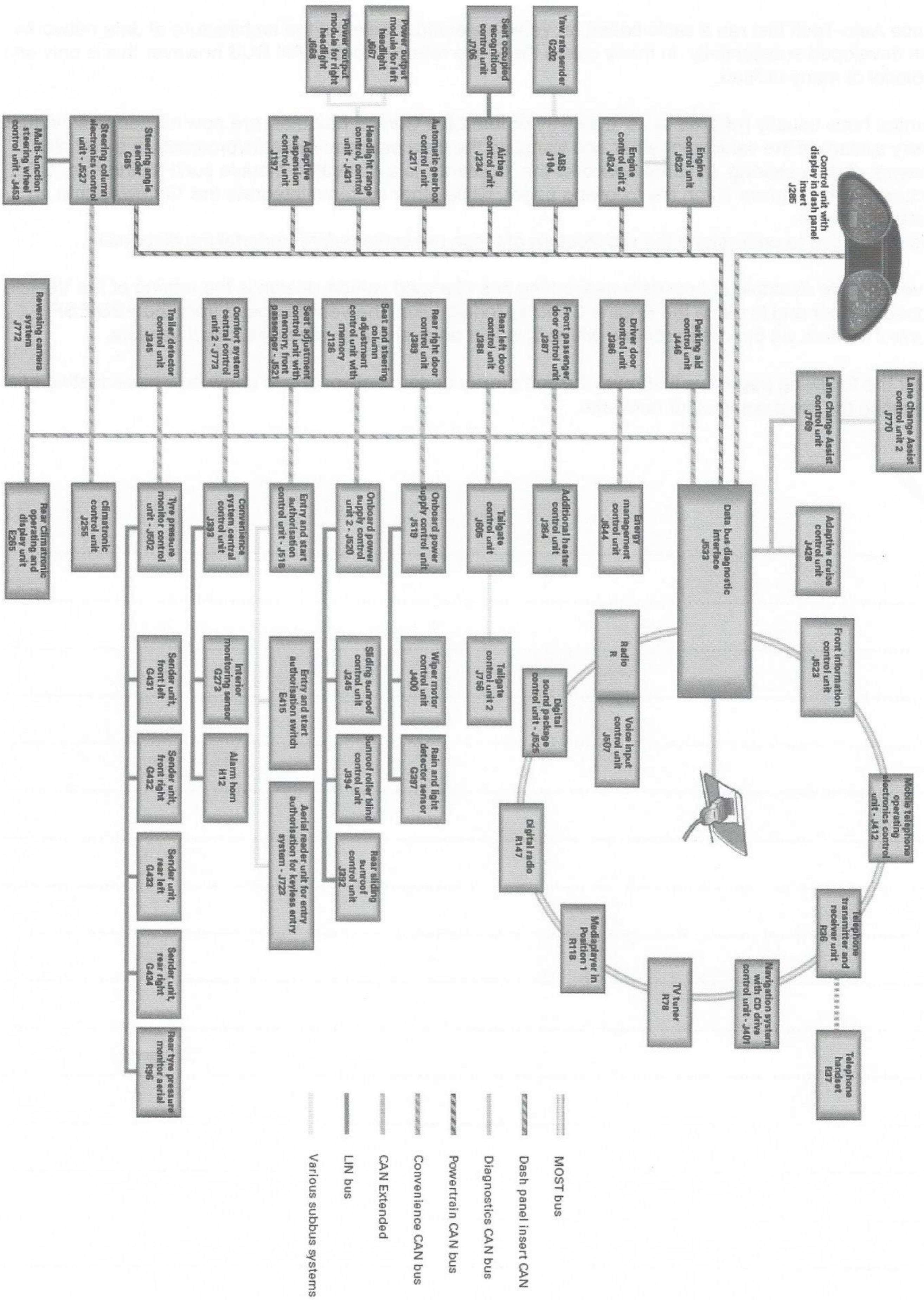

Control unit with display in dash panel insert J285
Engine control unit J623
Engine control unit 2 J624
ABS J104
Yaw rate sender G202
Airbag control unit J234
Seat occupied recognition control unit J706
Automatic gearbox control unit J217
Headlight range control, control unit - J431
Power output module for left headlight J667
Power output module for right headlight J668
Adaptive suspension control unit J197
Steering angle sender G85
Steering column electronics control unit - J527
Multi-function steering wheel control unit - J453
Lane Change Assist control unit 2 J770
Lane Change Assist control unit J769
Parking aid control unit J446
Driver door control unit J386
Front passenger door control unit J387
Rear left door control unit J388
Rear right door control unit J389
Seat and steering column adjustment control unit with memory J136
Seat adjustment control unit with memory, front passenger - J521
Comfort system central control unit 2 - J773
Trailer detector control unit J345
Reversing camera system J772
Adaptive cruise control unit J428
Data bus diagnostic interface J533
Energy management control unit J644
Additional heater control unit J364
Tailgate control unit J605
Onboard power supply control unit J519
Onboard power supply control unit 2 - J520
Entry and start authorisation control unit - J518
Convenience system central control unit J393
Tyre pressure monitor control unit - J502
Climatronic control unit J255
Rear climatronic operating and display unit E265
Front information control unit J523
Radio R
Voice input control unit J507
Tailgate control unit 2 J756
Digital sound package control unit - J525
Wiper motor control unit J400
Rain and light detector sensor G397
Sliding sunroof control unit J245
Sunroof roller blind control unit J394
Rear sliding sunroof control unit J392
Entry and start authorisation switch E415
Aerial reader unit for entry authorisation for keyless entry system - J722
Interior monitoring sensor G273
Alarm horn H12
Sender unit, front left G431
Sender unit, front right G432
Sender unit, rear left G433
Sender unit, rear right G434
Rear tyre pressure monitor aerial R96
Mobile telephone operating electronics control unit - J412
Digital radio R147
Telephone transmitter and receiver unit R36
Mediaplayer in Position 1 R118
TV tuner R78
Navigation system with CD drive control unit - J401
Telephone handset R37
MOST bus
Dash panel insert CAN
Diagnostics CAN bus
Powertrain CAN bus
Convenience CAN bus
CAN Extended
LIN bus
Various subbus systems

Diagram 10: 2007 Audi Q7 data network (Image source: Audi Germany)

DATA NETWORKING AND THE OBD CONNECTOR continued...

Before going anywhere near the Diagnostic Connector with a multimeter it is important understand the preferred connecting methods.

⚠ *Caution: You must NEVER test the OBD Connector by probing the front socket pins. Doing so may damage or stretch the pins which may lead to communication errors with a Scan Tool.*

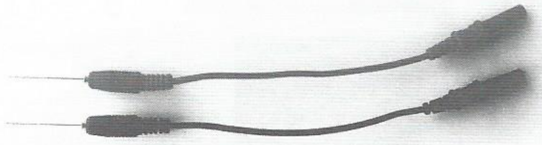


Diagram 11: Back-probing leads

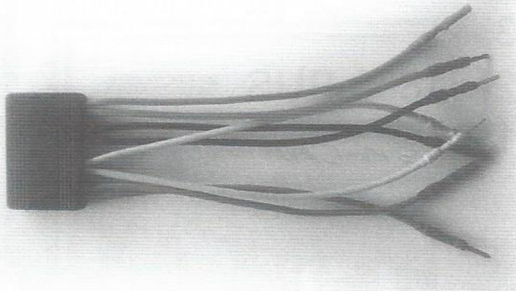


Diagram 12: Basic break-out plug

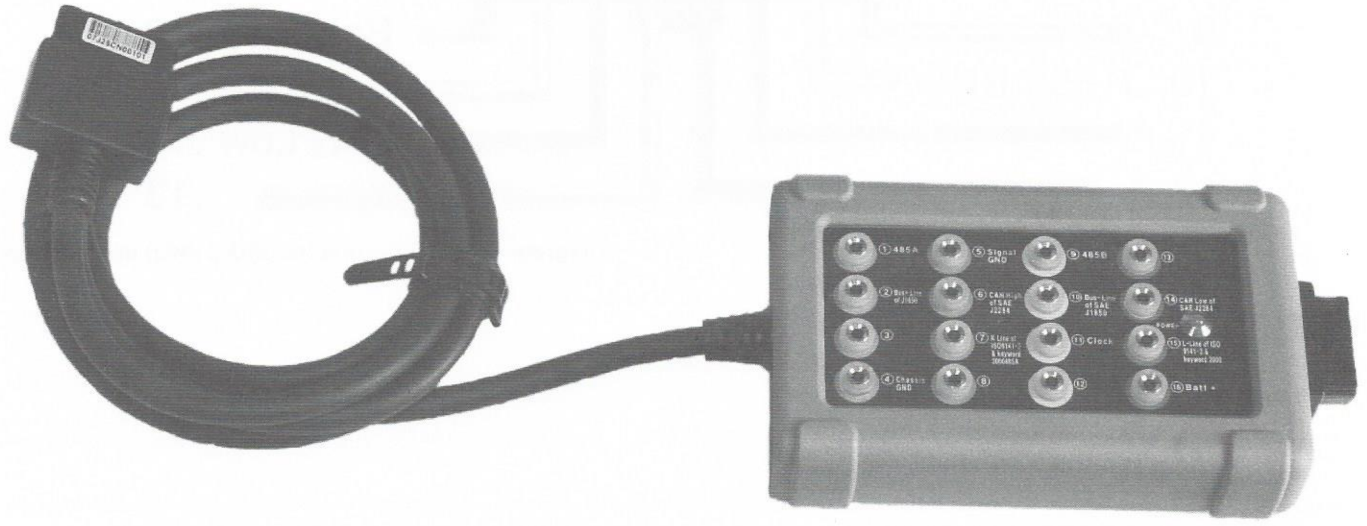

① 485A
② Bus+Line of J1850
③
④ Chassis GND
⑤ Signal GND
⑥ CAN High of SAE J2284
⑦ K Line of ISO9141-2 & keyword 2000
⑧
⑨ 485B
⑩ Bus-Line of SAE J1850
⑪ Clock
⑫
⑬
⑭ CAN Low of SAE J2284
POWER
⑮ L-Line of ISO 9141-2 & keyword 2000
⑯ Batt +

Diagram 13: Specialised OBD Connector pass through break-out box (Image source: Pico Technology)

All three of the above testing option allow for quick and easy testing at the diagnostic connector without risk of damage to the vehicle. The specialised Pico breakout box includes LED's rings that light up whenever there is electrical activity at a connector and it also includes a pass through OBD Connector for coupling a scan tool simultaneously.

DATA NETWORKING AND THE OBD CONNECTOR continued...

OBD Connector Designation

The designation of the OBD connector was initially set out by the US OBD-II standard in 1996 (although the same connector was used in earlier standards) as SAE-J1962 (see Diagram 14) and has been adopted into EOBD for the EURO-III implementation in 2001 as ISO-J1962. Because Australia did not implement the equivalent of these legislations until ADR79/01 in 2005/06 it is possible manufacturers to use a non-generic diagnostic connector prior to this point.

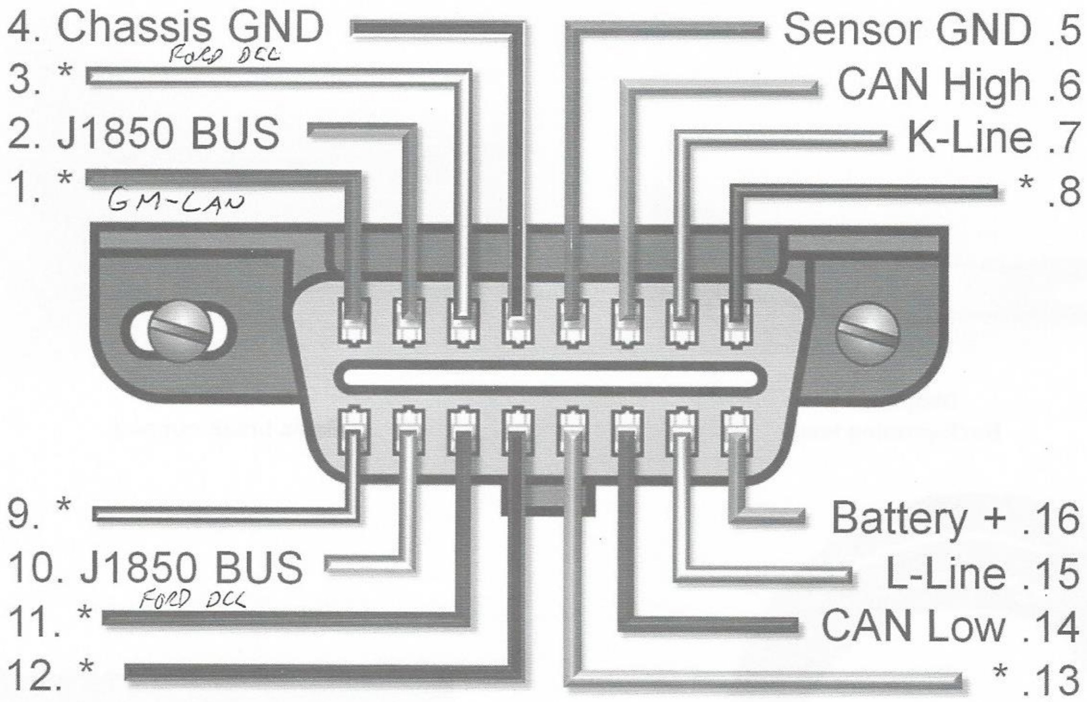

4. Chassis GND
3. *
FORD DCL
2. J1850 BUS
1. *
GM-LAN
Sensor GND .5
CAN High .6
K-Line .7
* .8
9. *
10. J1850 BUS
FORD DCL
11. *
12. *
Battery + .16
L-Line .15
CAN Low .14
* .13

Diagram 14: OBD Connector (ISO-J1962) designation

DATA NETWORKING AND THE OBD CONNECTOR continued...

Ground and Power circuits

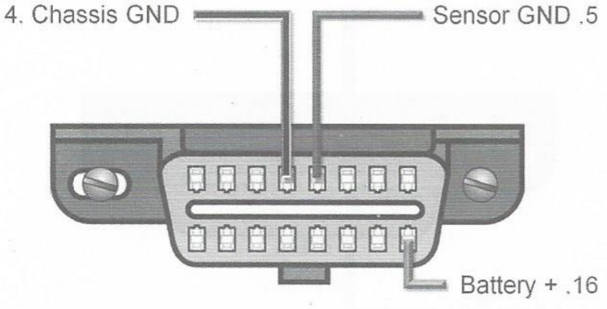


Diagram 15:
OBD Connector Ground and Power circuits

All vehicles fitted with a 16 pin OBD Connector should have the following:

Pin 4:
Chassis Ground
This has been the configuration standard for this connector since its recommendation by the SAE in 1988.

Pin 5:
Sensor Ground
(sometimes called Signal Ground)
The requirement for this circuit was added in 1996 in the US with the implementation of OBD-II and 2001 in Europe with the implementation of the EURO-III standard.
Unlike the Chassis Ground which is usually grounded to the nearest ground point to the connector, the Sensor Ground is grounded to the same ground point as the ECM.
While a lot of documentation states that you can test the ECM Ground at the OBD Connector this is NOT entirely correct as it does not allow for loss of ground between the ground point and ECM (damaged wiring) and most ECM's utilise multiple ground points.

Pin 16:
Unswitched Battery Volts

Discretionary circuits - Part I

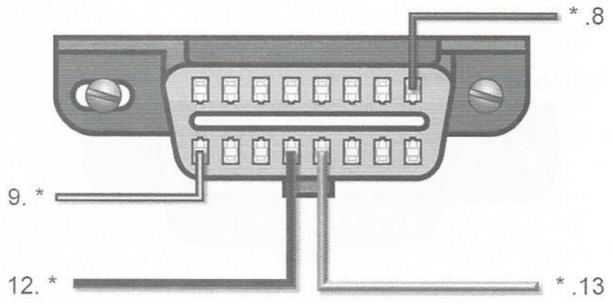


Diagram 16:
Discretionary circuits

Pins 8, 9, 12 and 13:
Discretionary circuits
These can be used by manufactures as they see fit. As these are discretionary there are no standard basic tests that can be applied.
Some example of manufacturers utilising these circuits are:

Toyota - Pin 13
Manual diagnosis switch

Nissan - Pin 8 <2005
Manual diagnosis switch

Nissan - Pin 8 >2005
Ignition Voltage

DATA NETWORKING AND THE OBD CONNECTOR continued...

Discretionary circuits – Part II

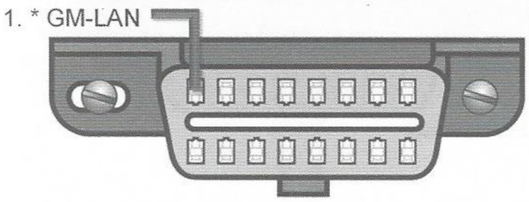


Diagram 17:
Discretionary circuit – GM Low Speed LAN

Pin 1:

GM Low Speed LAN

Here is an example of a manufacturer using another discretionary circuit.

GM/Holden use Pin 1 for communication with their single wire the Low Speed Network.

As this is discretionary there are no standard basic tests that can be applied. However, the GM Low Speed LAN operates on a similar basis as the K-Line signal except it is reversed. It is a basic binary code, the idle voltage is 0 Volts with a signal voltage of Battery Volts.

Note: *For full Holden VE series Serial Communication diagnostic testing procedures visit www.autopedia.net.au*

Discretionary circuits - Part III

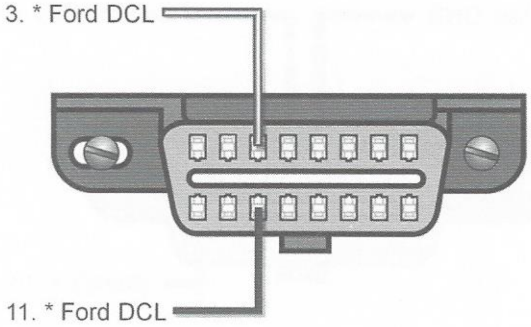


Diagram 18:
Discretionary circuits – Ford DCL Network

Pins 3 and 11:

Ford DCL Network

Here is another example of a manufacturer using a discretionary circuit.

Ford use Pins 3 and 11 for communication with their two-wire Medium Speed Network.

As this is discretionary there are no standard basic tests that can be applied. However, the Ford DCL Network is similar to CAN BUS in its configuration. Therefore the Resistance Test for CAN BUS (see *page 41*) is also appropriate for Ford's DCL Network.

Note: *For full FG Falcon Serial Communication diagnostic testing procedures visit www.autopedia.net.au*

DATA NETWORKING AND THE OBD CONNECTOR continued...

J1850 BUS circuits

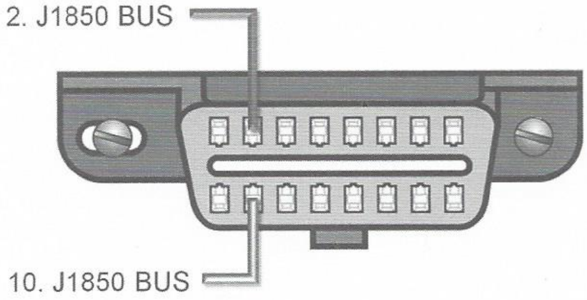


Diagram 19:
J1850 BUS circuits

There are 2 types of J1850 Networks:

Pin 2:
SAE-J1850 VPW
Used almost exclusively by GM in the US between 1996 & 2007 it is a single wire communication network (the only AU production vehicles to use this are the VY & VZ Gen III V8's)

Pin 2 and 10:
SAE-J1850 PWM
Used almost exclusively by Ford in the US between 1996 & 2007 it is a two wire communication network (the only AU production vehicles to use this are the AU series Falcons)

The SAE-J1850 PWM was pretty much a pre-curser for CAN BUS. It has many of the same capabilities, however J1850 was only recognised by SAE in the US so when OBDII was updated in 2008 the ISO CAN BUS protocol was adopted because of its international compliance.

ISO9141 and KWP2000

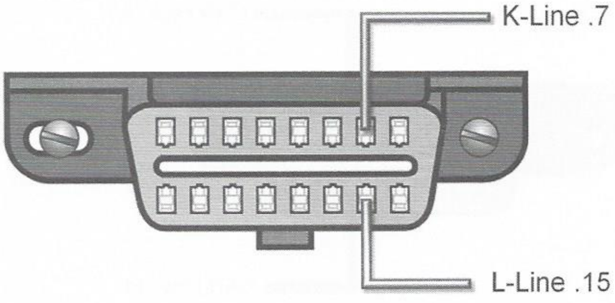


Diagram 20:
ISO9141 and KWP2000 circuits

The ISO9141-2 & ISO14230-4 (KWP2000) protocols are most commonly known as the K-Line & L-Line these are International Standard (ISO) protocols and were used for most pre-CAN BUS vehicles in Europe and Asia, as well as by the Chrysler group in the US. Therefore these are the most common pre-CAN BUS protocols in AU.

Pin 15:
L-Line
In very early ISO9141-2 protocols Scan Tools used the L-Line to send a request to the ECM to create a Link with the Scan Tool. Then all of the communication was done via the K-Line.

Pin 7:
K-Line
All other pre-CAN BUS ISO protocols do not require the L-Line and all communication is done on the K-Line (this is by far the most common pre-CAN BUS ISO configuration).

The K-Line signal is a basic binary code, the idle voltage is Battery Volts (Binary 1) with a signal voltage of 0 Volts (Binary 0).

The K-Line will not usually command a signal unless it is triggered to do so by a Scan Tool. Therefore if you wish to monitor the K-Line you'll need to back probe the diagnostic connector while it is connected to a Scan Tool.

The K-Line is of such basic design that is not able to communicate with multiple nodes (modules) simultaneously, it must connect with each node individually.

DATA NETWORKING AND THE OBD CONNECTOR continued...

CAN BUS circuits

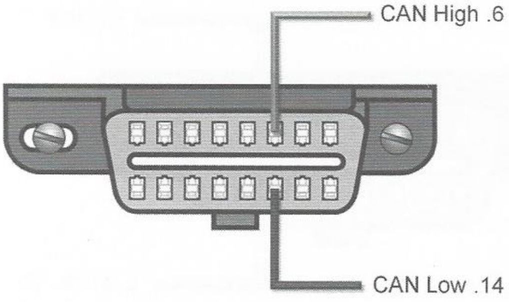


Diagram 21:
CAN BUS circuits

The CAN BUS (Controller Area Network Bi-directional Universal Signal) Network was developed by Bosch to fulfil its intra-vehicle communication needs. Although Bosch started on CAN BUS in 1983 and completed V1.0 in 1986 it wasn't until 2001 that it started to gain popularity.

There are 4 different BIT-rates variations in the protocol:

1.1 11bit/500Kb
1.2 29bit/500Kb
1.3 11bit/250Kb
1.4 29bit/250Kb

DATA NETWORKING AND THE OBD CONNECTOR continued...

CAN BUS Testing

Resistance

All CAN BUS networks utilise terminating resistors across each end of the network, these resistors absorb the signals once they have been received by the other nodes (modules). The terminating resistors can be stand-alone objects or they can be incorporated into a node, as can be seen in *Diagram 22* below.

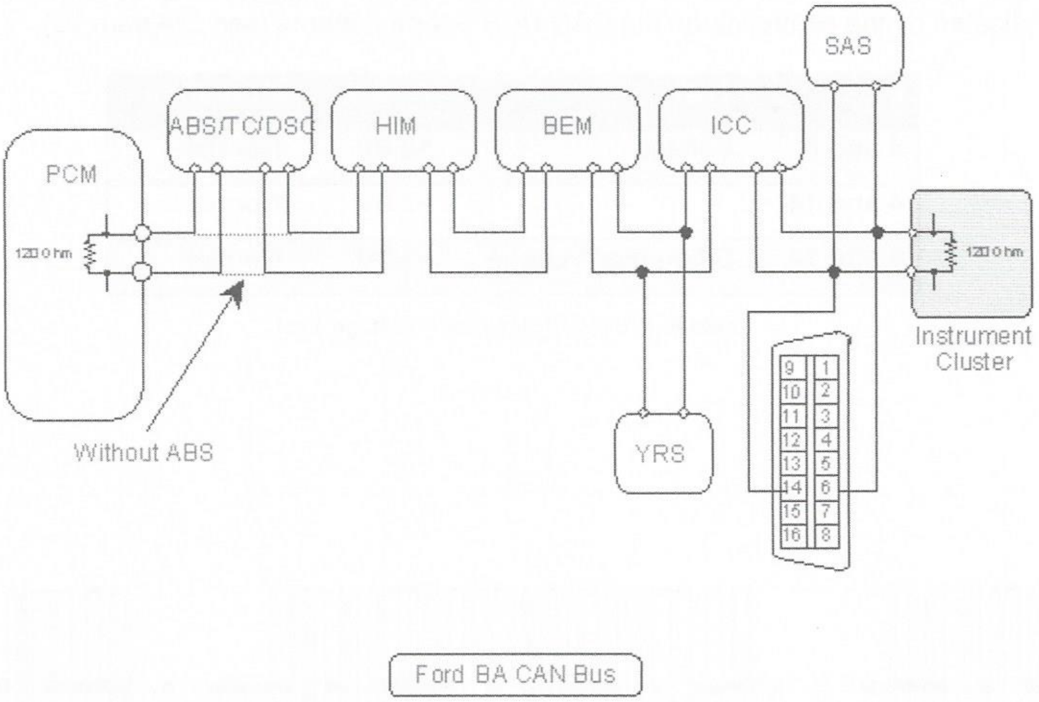


Diagram 22: Ford BA Falcon - CAN BUS Network

To test the resistance of a CAN BUS Network:

1. Disconnect the negative battery terminal
2. Measure resistance across pins 6 and 14 of the Diagnostic Connector
3. Results should be 60 Ohms resistance

Pins	Test	Result	Condition
6 and 14	Resistance	60Ω	Normal
		<60Ω	Short circuit
		120Ω	Open circuit
		∞ (Infinity)	Multiple open circuits

Table 5: CAN BUS Network – Resistance Test

Note: *If the test result is a short circuit, disconnect the Control Modules (Nodes) one at a time starting with the module furthest from the Diagnostic Connector. When the resistance returns to 120 Ohms or Infinite Ohms the short circuit can be found in either the module that was just disconnected or in the BUS line immediately prior.*

If the test result is an open circuit, work your way through the network testing from connector to connector until the open circuit is isolated.

DATA NETWORKING AND THE OBD CONNECTOR continued...

CAN BUS Testing

Voltage

Checking the CAN BUS voltages at the Diagnostic Connector checks how the Nodes (Control Modules) are using the network (as opposed to the Resistance test that checked the integrity of the network). Because of the speed of the BUS signals they are immeasurable with an Automotive Multimeter. Even quality Automotive Multimeter cannot measure signals faster than 1mS (0.001 Seconds). CAN BUS operates as quickly as 1µS (0.000001 Seconds). This is why the Multimeter display shows the average voltage as indicated by the centreline on the CAN BUS Scope patterns (see *Diagram 23*).

Pins	Test	Result	Condition
4 and 6	Voltage	≈3.0V	Normal
4 and 14		≈2.0V	Normal
6 and 14	Differential Voltage	≈1.0V	Normal

Table 6: CAN BUS Network – Voltage Test

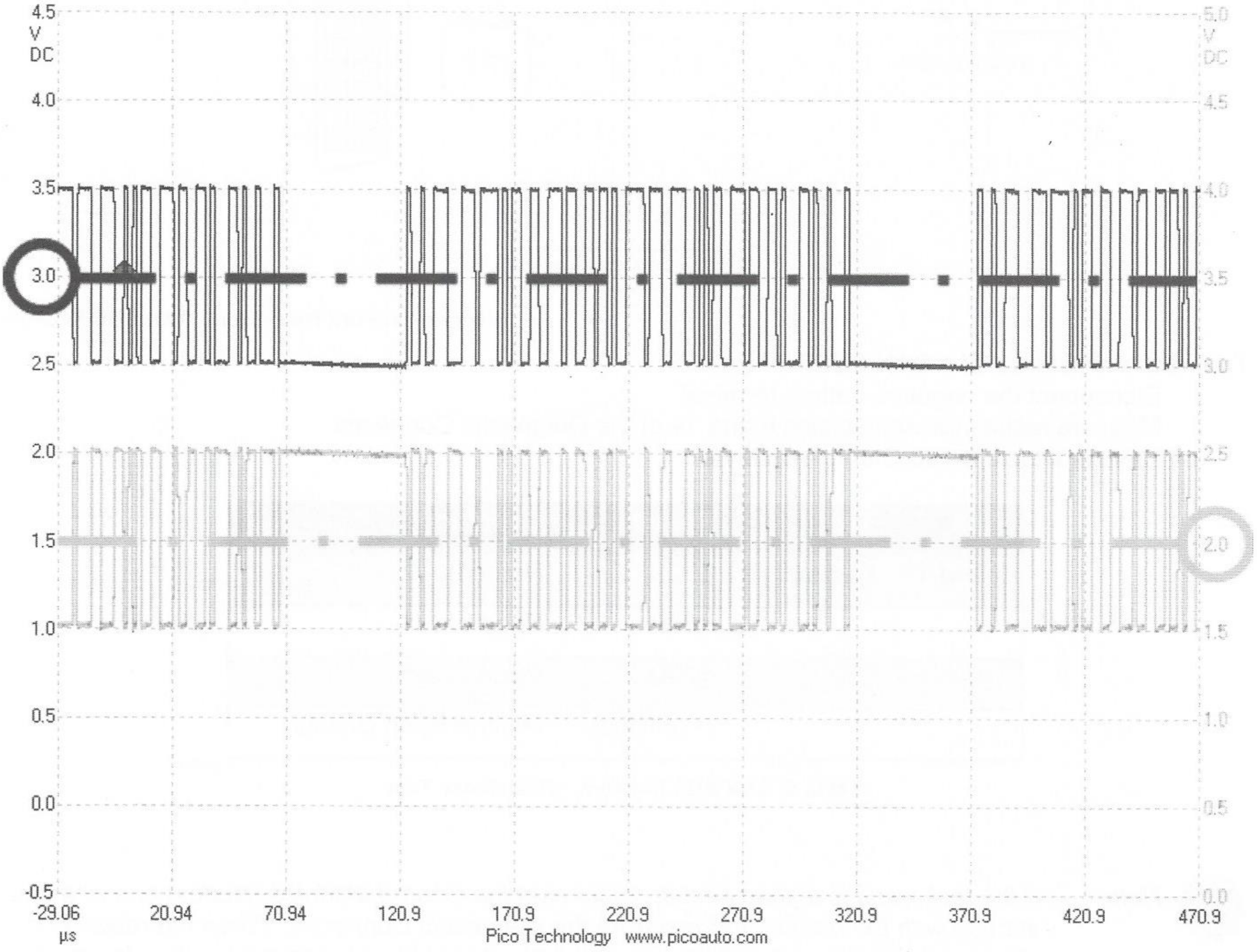


Diagram 23: Typical scope pattern of opposing CAN-High vs. CAN-Low (Image Source: Pico Technology)

DATA NETWORKING AND THE OBD CONNECTOR continued...

The CAN BUS protocol uses 2 signals that are a perfect mirror image of each other. Corrupted messages occur when Electro-Magnetic Interference (EMI) deforms the data signal. In Automotive vehicles the method used to reduce EMI is to twist the wiring (known as Twisted Pair), this means that with every twist the EMI is reversed and therefore cancels itself out (Twisted Pair wiring was first invented in 1881 to overcome interference in telephone wires caused by the introduction of Electric Trams).

As a secondary system in Automotive vehicles messages are sent simultaneously down two communication lines (CAN-High & CAN-Low). This allows nodes to identify corrupted message on the network and act upon them. When a corruption to a CAN message occurs it does not convert the complex message into a different readable complex message, it makes it unintelligible. This means that when (for example) the CAN-H message to the ECM translates to 'ENGAGE A/C Compressor yet the CAN-L is unintelligible the node knows that the desired command was 'ENGAGE A/C Compressor' and it can also log a CAN Communication DTC.

Diagram 24 below shows how using math channels on an oscilloscope make picking CAN BUS errors/corruption easy. If you look closely, the last pulse of Channel A is missing on Channel B. This example shows the communication error at the end of a sequence, if it was in the middle of a sequence it would be much harder to spot.

Math channels are a calculated scope pattern based on an equation, for this example there are 2 basic equations (A + B) and (A – B). Once applied the communication error is very easy to distinguish.

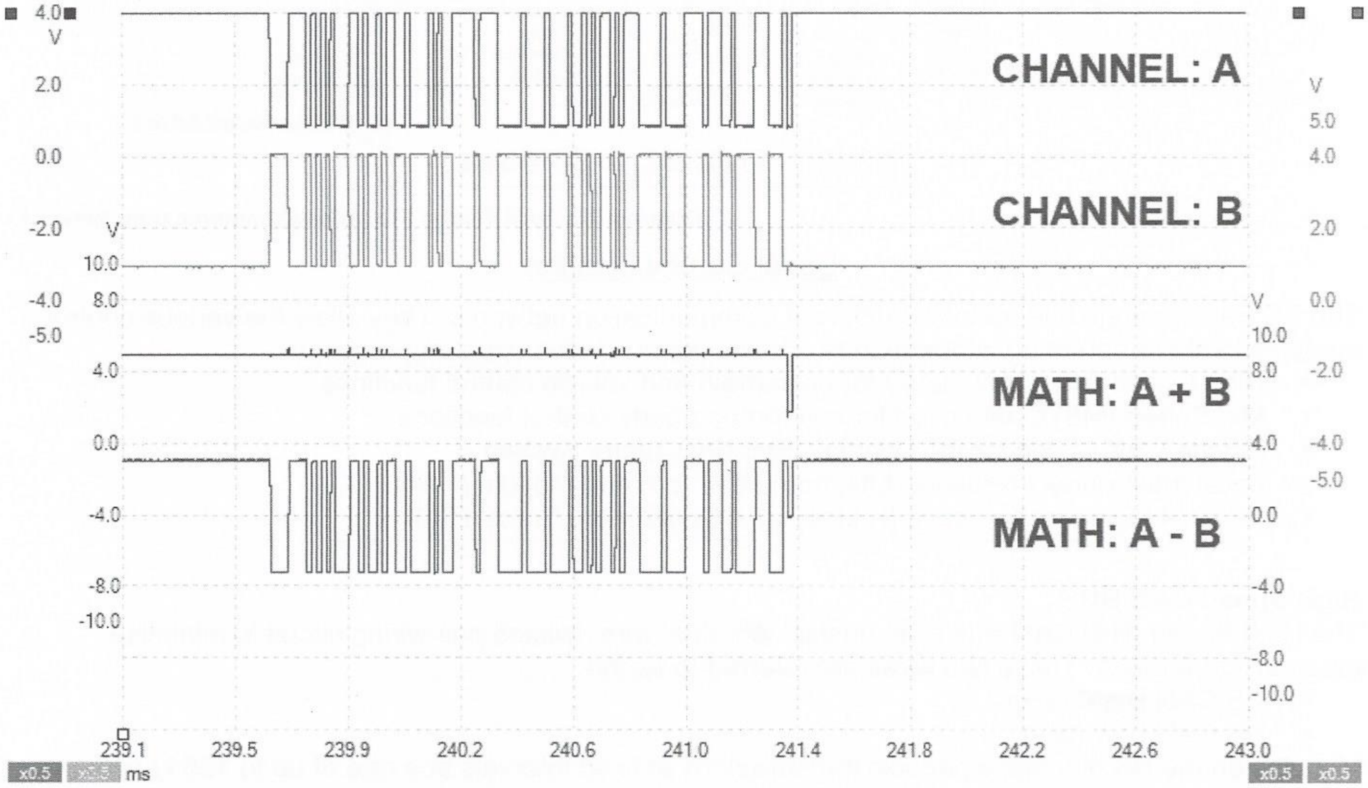


Diagram 24: Typical scope pattern of opposing data with error (Image Source: Autonerdz)

DATA NETWORKING AND THE OBD CONNECTOR continued...

Ford FG Falcon

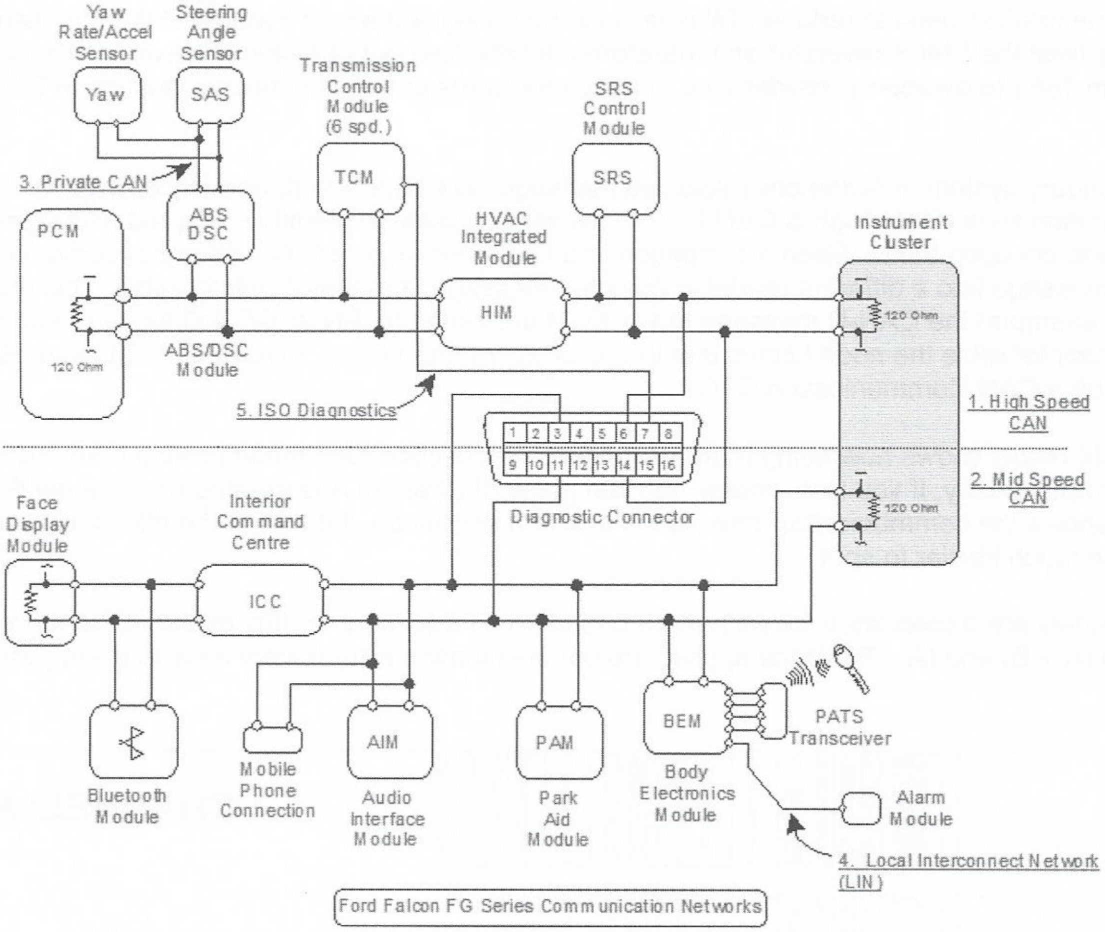

Yaw Rate/Accel Sensor
Yaw
Steering Angle Sensor
SAS
Transmission Control Module (6 spd.)
TCM
SRS Control Module
SRS
3. Private CAN
PCM
120 Ohm
ABS DSC
ABS/DSC Module
HVAC Integrated Module
HIM
Instrument Cluster
120 Ohm
5. ISO Diagnostics
1 2 3 4 5 6 7 8
9 10 11 12 13 14 15 16
Diagnostic Connector
1. High Speed CAN
2. Mid Speed CAN
120 Ohm
Face Display Module
Interior Command Centre
ICC
Bluetooth Module
Mobile Phone Connection
AIM
Audio Interface Module
PAM
Park Aid Module
BEM
Body Electronics Module
PATS Transceiver
Alarm Module
4. Local Interconnect Network (LIN)
Ford Falcon FG Series Communication Networks

Diagram 25: Ford Falcon FG series Communication Networks

Serial Communication

The FG Falcon range use up to five different Communication networks. They allow the various control modules to share operating information or communicate various operating requests:

- High Speed (HS) CAN - used for powertrain and vehicle control functions
- Mid Speed (MS) CAN - used for comfort and body control functions
- Private CAN - used for the Dynamic Stability Control System
- Local Interconnect Network (LIN) from BEM to Alarm Module (if fitted)
- ISO 9141 Diagnostic Circuit (K Line) for 6 Speed Auto Trans TCM

High Speed CAN BUS

The High Speed (HS) CAN Bus is an unshielded, dual wire, twisted pair wiring circuit to minimise external interference. These two wires are referred to as the:

- HS CAN High (or +)
- HS CAN Low (or -)

Modules on the HS bus make periodic transmissions at fixed intervals at a rate of up to 125 kbps. The High Speed (HS) CAN Bus contains the following modules and components:

- ABS / DSC ECM
- Airbag Control Module (SRS ECM)
- Automatic Transmission Control Module (TCM-6 Speed Auto)
- Diagnostic Connector
- HVAC Integrated Module (HIM)
- Instrument Cluster
- Powertrain Control Module (PCM)

DATA NETWORKING AND THE OBD CONNECTOR continued...

Medium Speed CAN BUS

The Mid Speed CAN Bus is an unshielded dual wire, twisted pair wiring circuit to minimise external interference.
These two wires are referred to as the:

- MS CAN High (or +)
- MS CAN Low (or -)

Each module in the CAN Bus is a "node" and sends and receives messages. Two "Terminating Nodes" are used, one is inside the PCM and the other is located in the Instrument Cluster. The terminating nodes contain 120 ohm resistors across each bus wire to prevent corruption of signals.
The Mid Speed (MS) CAN Bus is used for comfort and body control functions.

Modules in the MS CAN are:

- Audio Control Module.
- Audio Interface Module.
- Body Electronics Module
- Bluetooth Phone Module.
- Diagnostic Connector - Pins #3 and #11.
- Face Display Module.
- Interior Command Centre.
- Instrument Cluster.
- Parking Aid Module.

The MS CAN end Bus 120 Ohm resistors are located in the Instrument Cluster and the Face Display Module. Each module is connected in parallel. If one module is disconnected communication may still be possible between the remaining modules. If the Instrument Cluster is disconnected, it is not possible for the MS CAN Bus to communicate with the HS CAN Bus.

High Speed Private CAN – DSC

The Dynamic Stability Control System (if fitted) uses a Private CAN Bus.
This network connects the DSC ECM (ABS / DSC Module) with the:

- Steering Angle Sensor.
- Yaw Rate / Acceleration Sensor.

The Private CAN Bus resistors are located in the DSC ECM and the Yaw Rate / Acceleration Sensor.

Local Interconnect Network (LIN)

The LIN is between the Body Electronics Module (BEM) and the Alarm Module (if fitted).
It is a Single wire network. A LIN consists of a single Master module and one or more slave modules.
The Master Module communicates at a rate of up to 20 kbps (20,000 bits per second).

ISO 9141 Diagnostic Network (6 Speed Auto Trans)

The ISO 9141 Diagnostic Network is a single wire network used for diagnostics only.
There is no communication between modules on this network, only from the scan tool to the TCM.
ISO 9141 communicates at up to 10.4 kbps (10,400 bits per second).
The ISO Diagnostic line is connected to the Diagnostic Connector Pin #7.

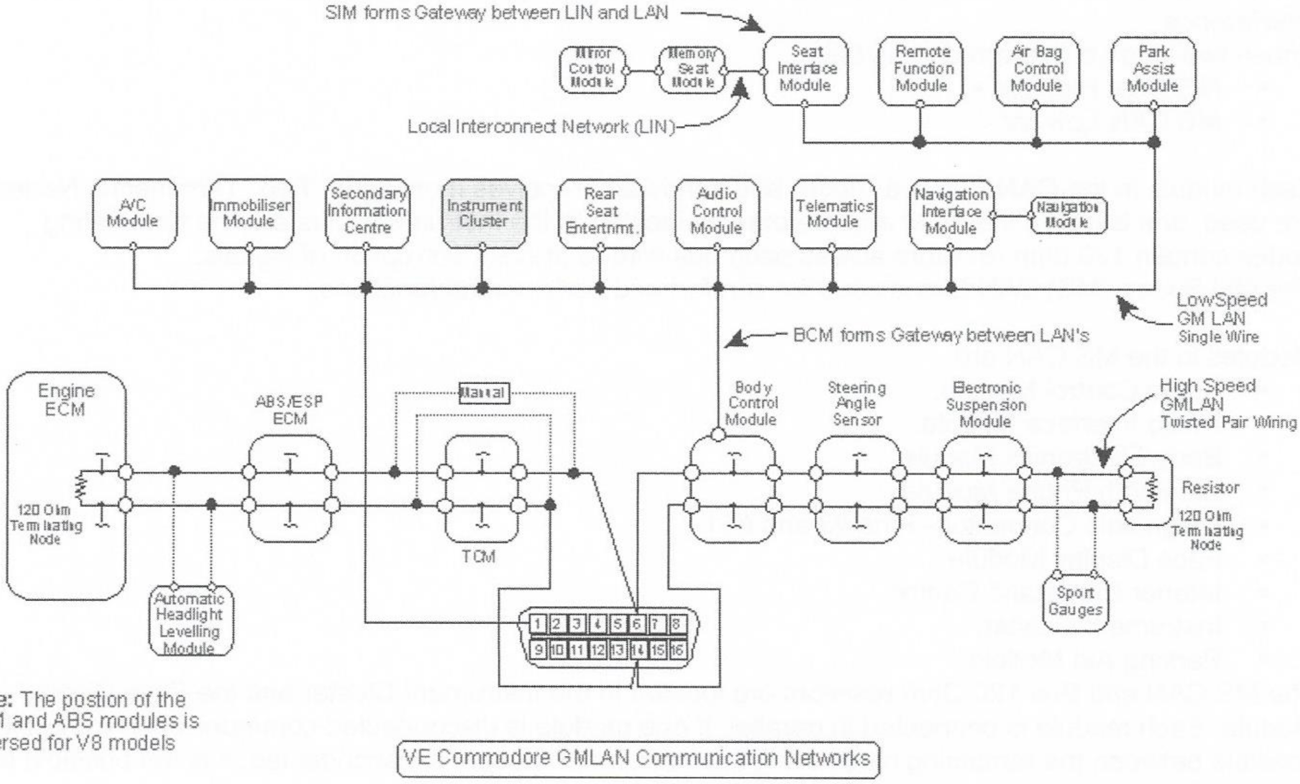
Network Gateway

The Instrument Cluster forms the Gateway between the High Speed and Mid Speed CAN Bus.
Data is shared between networks via the Instrument Cluster.

Note: *For full FG Falcon Serial Communication diagnostic testing procedures visit www.autopedia.net.au*

DATA NETWORKING AND THE OBD CONNECTOR continued...

Holden VE series


SIM forms Gateway between LIN and LAN
Mirror Control Module
Memory Seat Module
Seat Interface Module
Remote Function Module
Air Bag Control Module
Park Assist Module
Local Interconnect Network (LIN)
A/C Module
Immobiliser Module
Secondary Information Centre
Instrument Cluster
Rear Seat Entertnmt.
Audio Control Module
Telematics Module
Navigation Interface Module
Navigation Module
LowSpeed GM LAN Single Wire
BCM forms Gateway between LAN's
Engine ECM
ABS/ESP ECM
Manual
Body Control Module
Steering Angle Sensor
Electronic Suspension Module
High Speed GMLAN Twisted Pair Wiring
Resistor
120 Ohm Terminating Node
120 Ohm Terminating Node
TCM
Automatic Headlight Levelling Module
Sport Gauges
1 2 3 4 5 6 7 8
9 10 11 12 13 14 15 16
VE Commodore GMLAN Communication Networks

Note: The postion of the TCM and ABS modules is reversed for V8 models

Diagram 26: Holden VE series Communication Networks

Serial Communication

The GMLAN (General Motors Local Area Network) uses three different sub-systems which allow the various control modules to share operating information or communicate various operating requests:

- High Speed (HS) GMLAN Communication Bus.
- Low Speed (LS) GMLAN Communication Bus.
- Local Interconnect Network (LIN).

High Speed GMLAN Communication Bus

The High Speed GMLAN is a GM development of the familiar Bosch CAN System.
GMLAN is built on the CAN protocol foundation and is modified to accommodate elements specific to the GM applications. The HS GMLAN Communication bus is a dual wire, twisted pair wiring circuit to minimise external interference.
These two wires are referred to as the:

- GMLAN High (or +)
- GMLAN Low (or -)

....

....

....

....

....

DATA NETWORKING AND THE OBD CONNECTOR continued...

Low Speed GMLAN Communication Bus

The LS GMLAN Communication bus is a single wire circuit.

Modules on this bus make transmissions when an event occurs at a rate of 33.33 kbps.

An event can be simply when the Air Bag Module requires the Instrument Cluster to switch on the Air Bag Warning Lamp if a fault occurs in the Air Bag system.

The LS GMLAN links the:

- Air Bag Control Module
- Air Conditioner Control Module
- Audio Control Module
- Body Control Module - as the Gateway to HS GMLAN
- Immobiliser Module
- Instrument Cluster
- Navigation Interface Module
- Park Assist Module
- Rear Seat Entertainment Module
- Remote Function Module
- Seat Interface Module
- Secondary Information Centre
- Telematics Module (If fitted)
- Diagnostic Connector

Each module is connected in parallel.

If one module is disconnected communication will still be possible between the remaining modules.

If the BCM is disconnected, it is not possible for the LS GMLAN to communicate with the HS GMLAN.

Local Interconnect Network (LIN)

These vehicles also use another type of sub-network called a Local Interconnect Network (LIN) between small groups of modules.

Modules connected to a LIN are:

- Seat Interface Module – to the Memory Seat Module and the Mirror control Module.
- Navigation Interface Module – to the Navigation Module.

The Memory Seat Module and the Mirror Control Module operate using a UART protocol or digital language (Universal Asynchronous Receiver Transmitter).

The Seat Interface Module acts as a Gateway between these modules.

Note: *For full Holden VE series Serial Communication diagnostic testing procedures visit www.autopedia.net.au*

In practical terms...

This chapter investigates 4 diagnostic examples, these are:

- Integrated and Hidden Relays
- Heating, Ventilation and Air Conditioning (HVAC)
- Electronic Power Steering (EPS)
- Electronic Parking Brake (EPB)

INTEGRATED AND HIDDEN RELAYS

From the first vehicle electrical systems through to the 1970's manufacturers would place relays around the vehicle on a where required basis

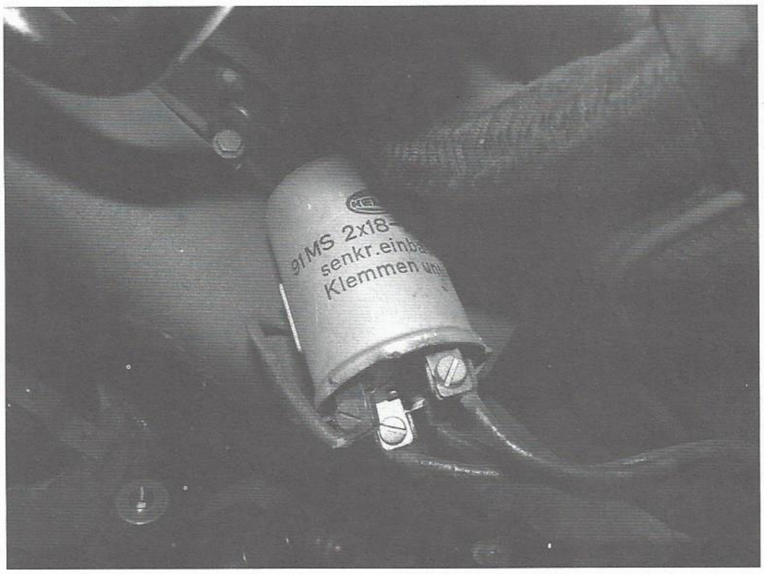


Image 1: Flasher Relay

Then, manufacturers started moving them into tidy and easy to access groups of 1 or 2 Fuse/Relay Boxes and locating them in sensible places such as the corner of the engine bay and the RHS of the dash panel.

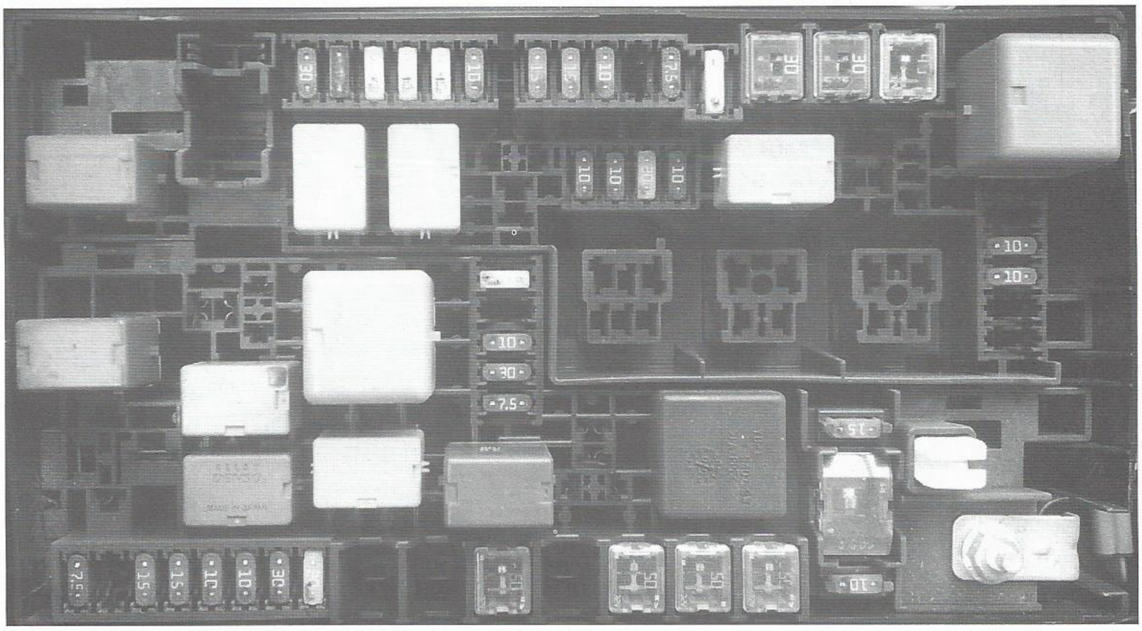


Image 2: Toyota Engine Bay Fuse/Relay Box

INTEGRATED AND HIDDEN RELAYS continued...

Now...

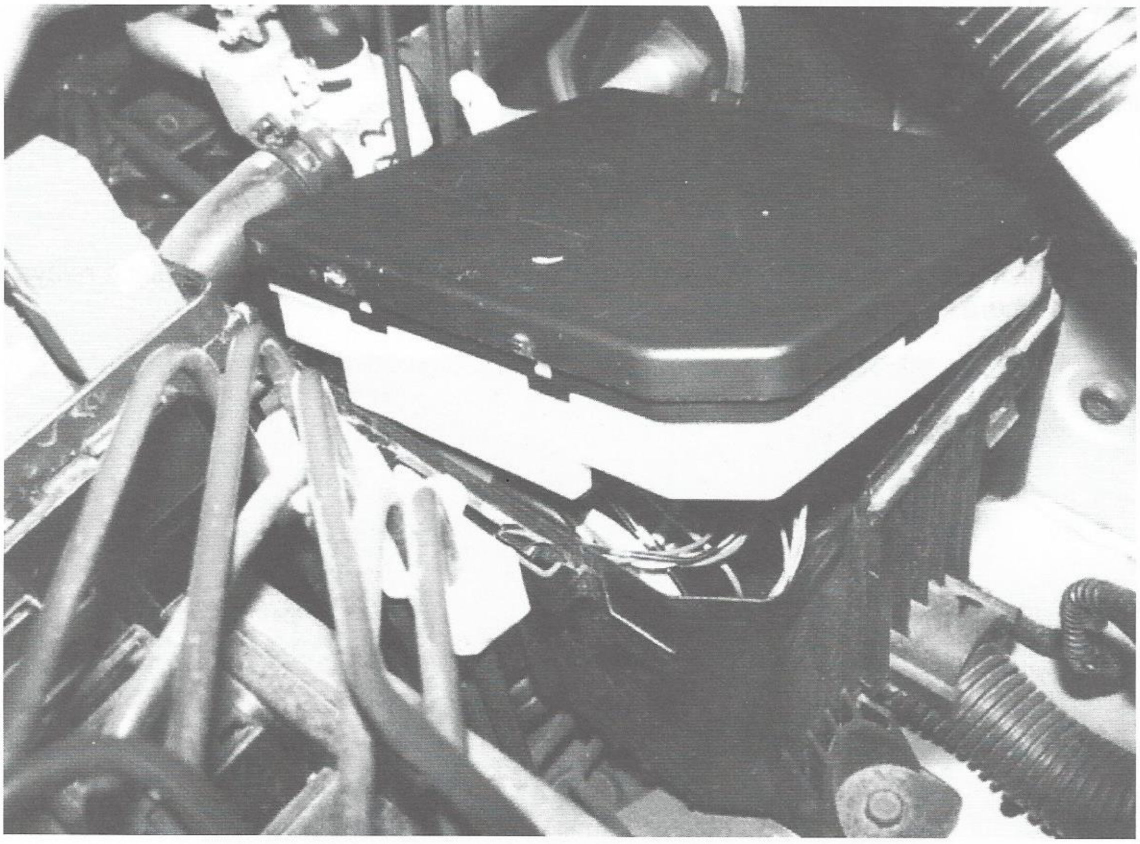


Image 3: Nissan Intelligent Power Distribution Module, Engine Room (IPDM-E/R) - Unlatched

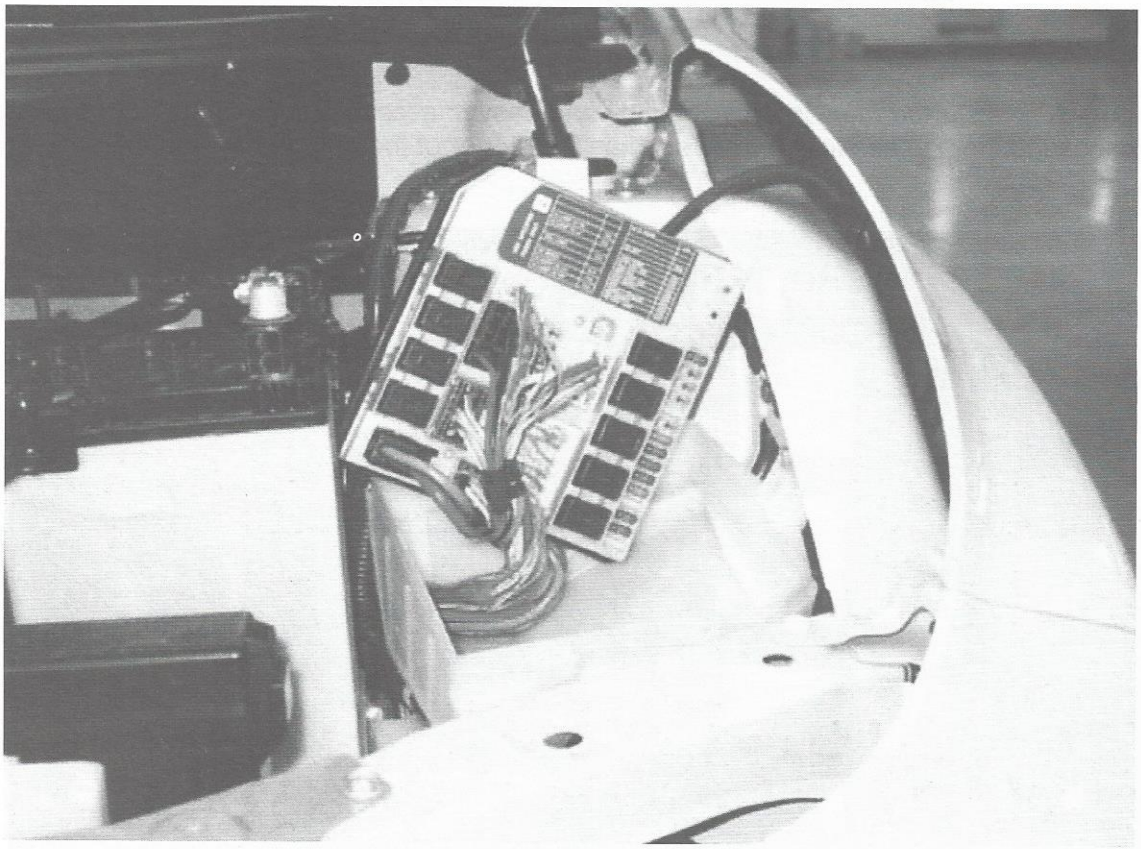


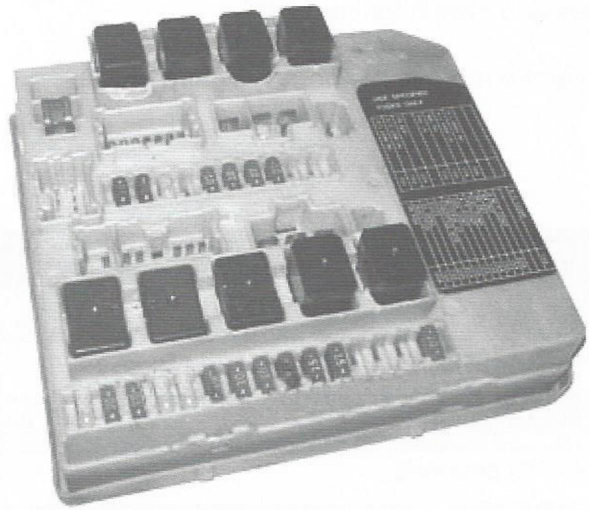
Image 4: Nissan Intelligent Power Distribution Module, Engine Room (IPDM-E/R) - Inversed

INTEGRATED AND HIDDEN RELAYS continued...

Nissan Intelligent Power Distribution Module - Engine Room (IPDM-E/R)

Amusingly called the Intelligent Power Distribution Module - Engine Room (IPDM-E/R), Nissan locates a series of Fuses & Relays on the underside of this module. Access is achieved by separating the module from its mounting box. In some cases there is insufficient length in the wiring loom and the harness must be disconnected (after disconnecting the Battery) to allow the replacement of fuses and relays.

Note: *The IPDM-E/R is on the CAN BUS Network and contains one of the terminating nodes for the network.*



Nissan models list of vehicles fitted with an IPDM-E/R:

- 350Z & 370Z
- Dualis
- Maxima 2003 on
- Micra 2007 on
- Murano
- Navara D40
- Pathfinder R51
- Tiida
- XTRAIL T31

Of these, a number suffer from premature ECM Relay failure. Nissan has recalled a number of the 2004-2006 Tiida, Navara & Pathfinder models.

Note: *According to the ACCC, an issue exists where Silicone Oxide is emitted from the internal diode that leads to contamination of the relay contacts and eventual engine stall or no start situations. If replacing the ECM Relay, ensure that the revised part is used*

Specific details on the recall can be found by searching 2010/12094 on www.recalls.gov.au.

Caution: *Relays are firmly fastened into the IPDM-E/R, care must be taken not to damage the module while removing the relays.*

If replacing the ECM Relay, check the cost of the entire IPDM-E/R as in some cases there is very little difference in cost.

Warning: *Various online forums discuss swapping the Fog Lamp Relay to the ECM location as a temporary fix. This is NOT recommended as it does not contain a diode and could result in damage to the ECM.*

INTEGRATED AND HIDDEN RELAYS continued...

IPDM-E/R Active Test

The Power Distribution Module has an Active Test function, that when enabled causes it to switch ON many of the systems that it contains relays and fuses for. This test allows us to confirm various circuits and their ability to function. If one of the functions below does not occur, then it confirms a fault in the circuit AFTER the Intelligent Power Distribution Module.

To initiate Active Test:

1. Switch Ignition OFF.
2. Close bonnet and lift wipers off windscreen, close all doors - except driver's door.
3. Switch Ignition ON.
4. Within 20 seconds, press drivers door switch 10 times and switch Ignition OFF.
5. Within 10 seconds, switch Ignition back ON.
6. Active Test begins (Oil Lamp begins flashing and on some models the horn will chirp once).

The test repeats for three cycles.
Test can be terminated by switching Ignition OFF.

Step	Test Item		Operation Time/Frequency
1	Rear Demister		ON – 10 seconds
2	Front Wiper		Low, 5 secs. – High, 5 secs.
3	Park Lamps (and Fog on some)		ON – 10 seconds
4	Fog Lamps (on some models)		ON – 10 seconds
5	Headlamps		Low, 10 secs. – High, ON-OFF 5 secs.
6	A/C Compressor		ON, 2 secs. – OFF, 5 secs (5 times)
7	Cooling Fans	2 Speed 3 Speed	Low, 5 secs. – High, 5 secs Lo – Mid – Hi – Mid – Lo @ 2 secs

Table 7: Nissan IPDM-E/R – Active Test

INTEGRATED AND HIDDEN RELAYS continued...

Holden VZ Commodore – BCM

The VZ series vehicles have a rather common concern where the integrated relay responsible for flashing the indicator lamps when the immobiliser is activated/deactivated fails.
This causes one or more of the following conditions:

- Indicators to lock ON
- Heat damage to Indicator Lenses
- Flat Battery

This relay is NOT the flasher relay it is only there for the Immobiliser flash function. Therefore if the relay is removed from the circuit board of the BCM the indicators are free to function normally but with no flash when the immobiliser is activated/deactivated.

Alternatively, replacement relays are readily available from electronic component suppliers. This repair costs substantially less than the cost of a new BCM.

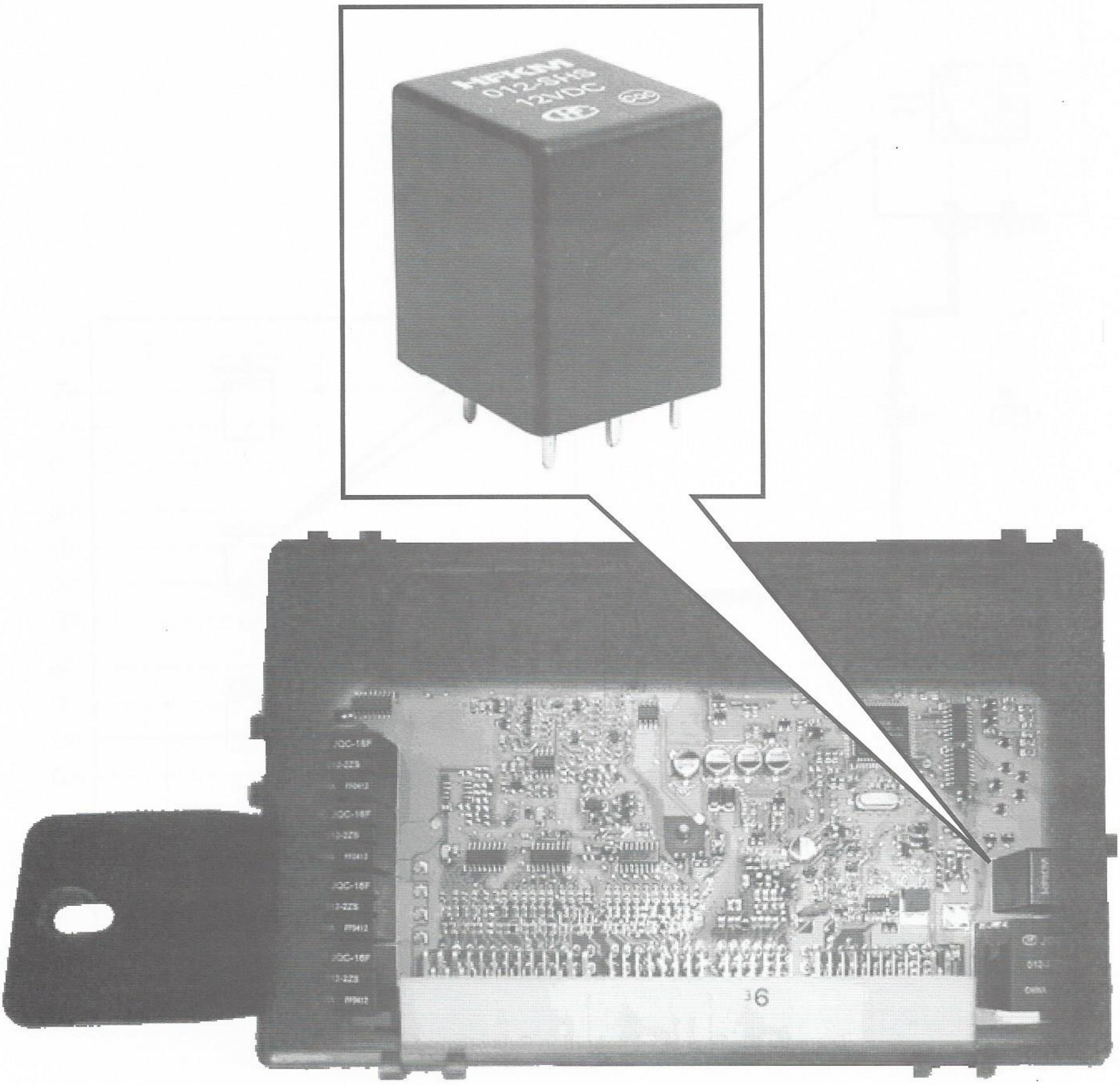


Image 5: Holden VZ Commodore - BCM

INTEGRATED AND HIDDEN RELAYS continued...

Toyota – Integration Relay

From the System Wiring Diagram (see *Diagram 27*), there is very little evidence to suggest that the Horn relay is anything other than a basic relay. However, by searching out the horn relay connector '1I' (see *Diagram 27*) the true complexity of this relay is revealed.

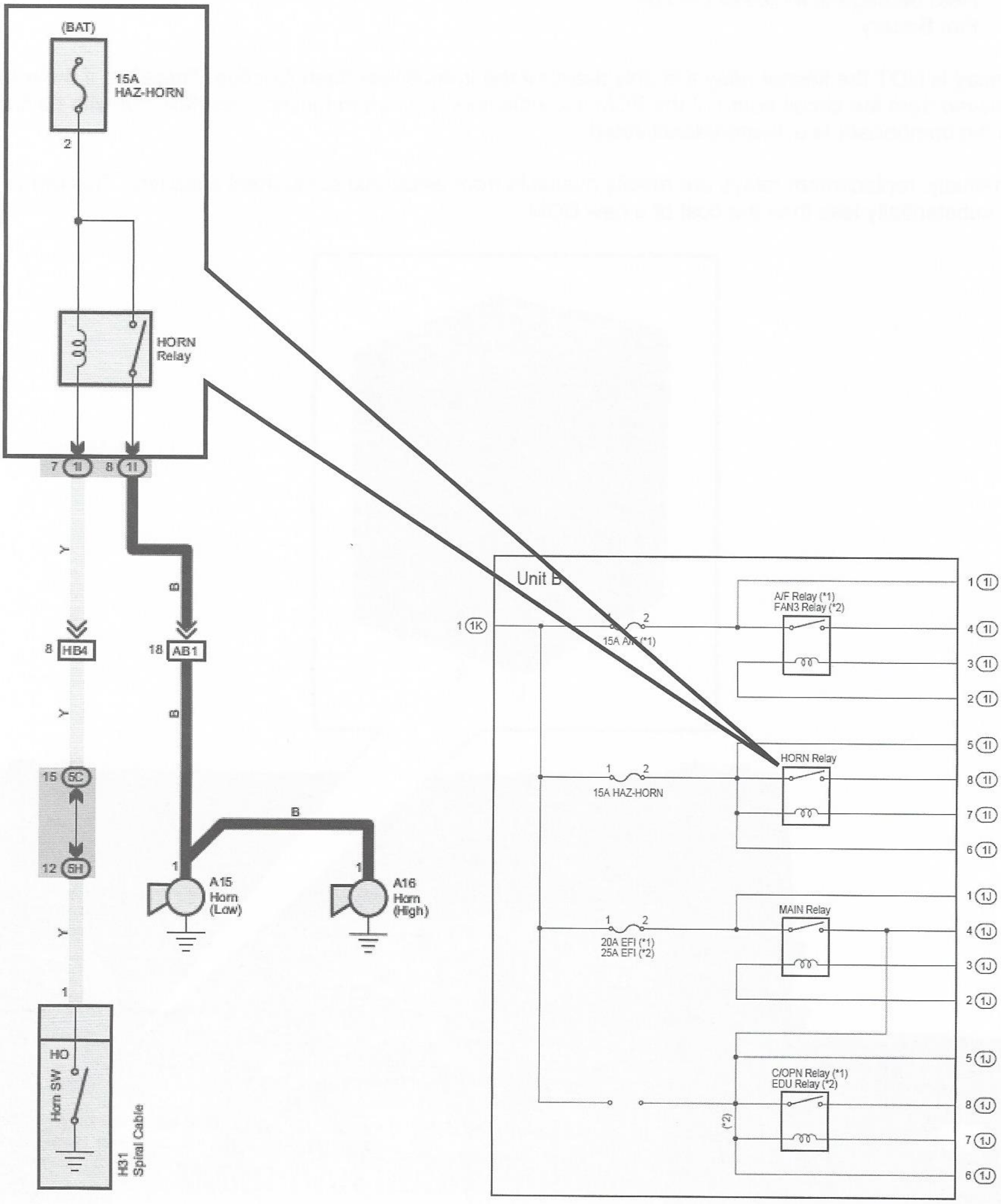

(BAT)
15A HAZ-HORN
2
HORN Relay
7 1I
8 1I
Y
B
8 HB4
18 AB1
15 5C
12 5H
A15 Horn (Low)
A16 Horn (High)
1
HO
Horn SW
H31 Spiral Cable
Unit B
1 1K
15A A/F (*1)
A/F Relay (*1)
FAN3 Relay (*2)
1 1I
4 1I
3 1I
2 1I
5 1I
HORN Relay
15A HAZ-HORN
8 1I
7 1I
6 1I
MAIN Relay
20A EFI (*1)
25A EFI (*2)
1 1J
4 1J
3 1J
2 1J
5 1J
C/OPN Relay (*1)
EDU Relay (*2)
(*2)
8 1J
7 1J
6 1J

Diagram 27: Toyota – Integration Relay (Image source: Toyota)

HEATING, VENTILATION AND AIR CONDITIONING (HVAC)

Holden VE Series I – Actuators

Nowadays, most makes and models are now fitted with HVAC systems available in the single, dual and tri zone configurations which rely on the use of Electronic Actuators to control the air temperature and direction. To simplify production the majority of manufacturers (inc. Holden) develop a single HVAC Assembly per model range capable of operating 3 individual zones then downgrade the Control Panel to suit dual and single zone models.

For the VE Commodore Series I, the HVAC unit is capable of Tri-zone operation however it is downgraded to Single or Dual-zone for low and medium spec models respectively.

Note: *For the VE Series II, Holden modified the HVAC system slightly and dropped the Single-zone option.*

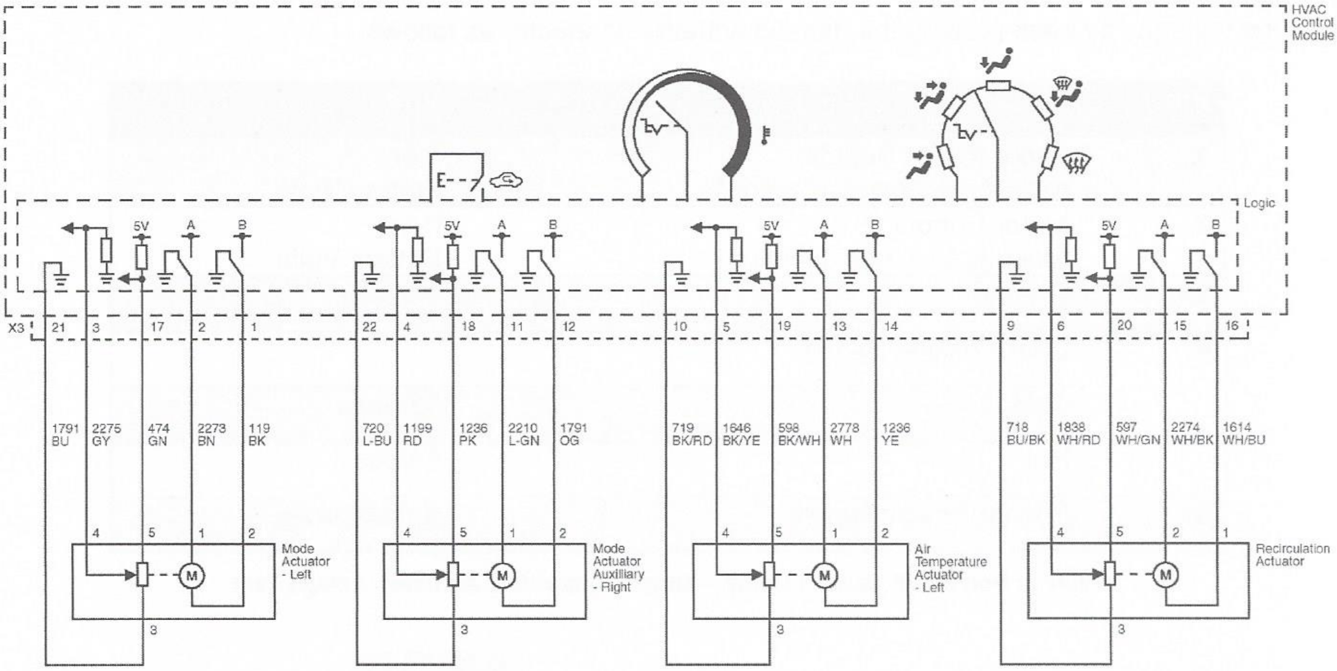

HVAC Control Module
Logic
5V
A
B
X3
21
3
17
2
1
22
4
18
11
12
10
5
19
13
14
9
6
20
15
16
1791 BU
2275 GY
474 GN
2273 BN
119 BK
720 L-BU
1199 RD
1236 PK
2210 L-GN
1791 OG
719 BK/RD
1646 BK/YE
598 BK/WH
2778 WH
1236 YE
718 BU/BK
1838 WH/RD
597 WH/GN
2274 WH/BK
1614 WH/BU
M
Mode Actuator - Left
Mode Actuator Auxiliary - Right
Air Temperature Actuator - Left
Recirculation Actuator

Diagram 28: Holden VE Series I Utility – Single-Zone HVAC Actuator Wiring Diagram (Image source: GM/Holden)

HEATING, VENTILATION AND AIR CONDITIONING (HVAC) continued...

Actuator Testing

While HVAC actuators can be tested on a Scan Tool using functions such as:
- DTC Analysis
- Data Analysis
- Actuation Tests

The fact is that unless you have a factory Scan Tool the software that allows the tool to communicate with that vehicle has been reverse engineered. The reality of this is that while your Scan Tool might function well on most of the tasks you undertake, you may find that less common tests like those listed above are not fully accessible.

Scan Tool Testing

Wherever possible use your Scan Tool to diagnose faults within the HVAC system.

Voltage Tests

Test the voltages by back-probing the desired actuator connector as follows:

Pin	Circuit	Volts
1	Motor Power Supply (polarity switches direction)	0 or Battery Volts
2	Motor Control (polarity switches direction)	0 or Battery Volts
3	Ground	0 Volts
4	Door Position Sensor	
	Cold	10 Volts
	Hot	0 Volts
5	Sensor Power Supply	Battery Volts

Table 8: Holden VE Series I Utility – Single-Zone HVAC Actuator Voltage Test

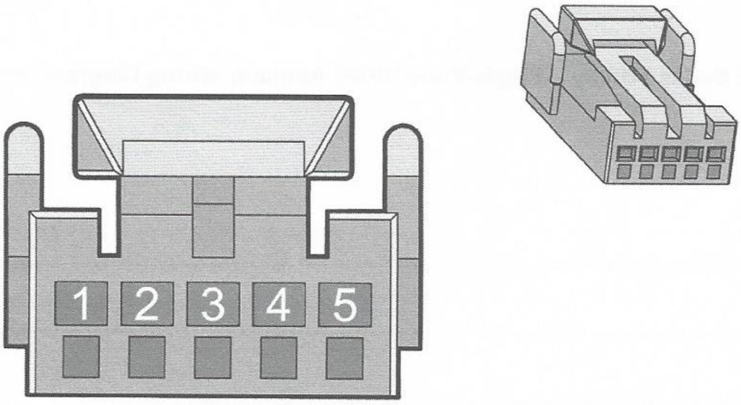


Diagram 29: Holden VE Series I Utility –Actuator Connector

Back-probing View on left / Face View on right

HEATING, VENTILATION AND AIR CONDITIONING (HVAC) continued...

Resistance Tests

Test the resistances by disconnecting the desired actuator connector and testing as follows:

Pins	Circuit	Ohms
1 and 2	Motor	36 Ω
3 and 5	Door Position Sensor	145 kΩ

Table 9: Holden VE Series I Utility – Single-Zone HVAC Actuator Resistance Test

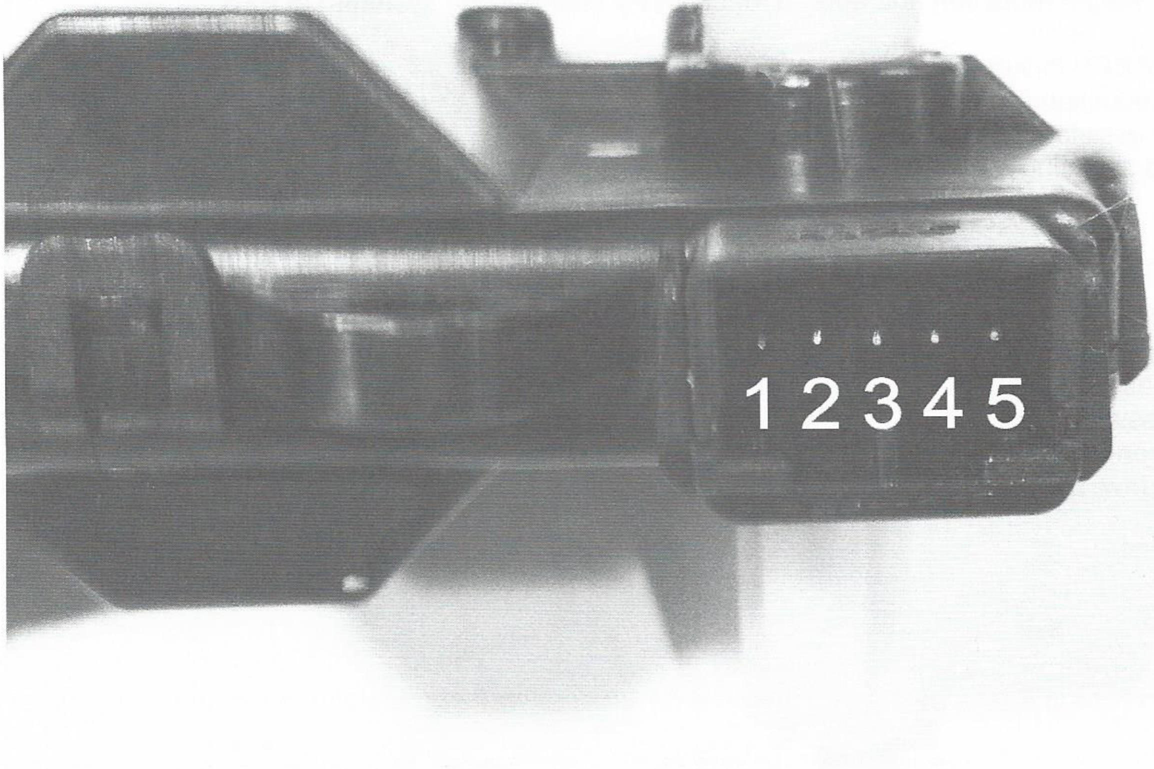


Image 6: Holden VE Series I Utility –Actuator

Manual Actuation Test

If you do not have a compatible Scan Tool you can manually initiate an actuation test. In the first instance ensure that all Actuators can be heard functioning. Secondly, back probe terminal 4 of each actuator with a Voltmeter and ensure that they are outputting between 0 and 12 Volts.

Test as follows:

1. Ignition ON, Engine OFF
2. Remove Glove Box and Panels as required
3. Press Rear Demist button until actuators can be heard
4. Listen to each Actuator with a stethoscope

ELECTRONIC POWER STEERING (EPS)

Belt driven Hydraulic Power Steering systems are required to deliver maximum assistance during times when the engine is running at its slowest. This means that when the engine is at high revs, the power steering pump is applying unnecessary load on the engine. The differences in engine load between hydraulic & electronic power steering system can be seen in *Table 10.*

Drive Cycle	Hydraulic	Electronic
Urban	> 0.5kW	~ 0.03kW
Extra Urban	> 1.0 kW	~ 0.01 kW

Table 10: Power Steering engine load – Hydraulic vs. Electronic (Data source: VW)

Electro-Hydraulic Power Steering systems go some way to overcoming these concerns, however they do not address the weight reduction and add-on functionality (self-parking systems) of EPS.

Other benefits of EPS include:

- Weight reduction (> 50%)
- Variable assistance is easily achieved
- Reduced servicing

EPS Configurations/Drive Systems

EPS systems are available in 4 configurations based on the way or position that the drive assistance is applied. The 4 configurations are:

1. Column assisted EPS
2. Pinion assisted EPS
3. Dual pinion EPS
4. Parallel drive EPS

ELECTRONIC POWER STEERING (EPS) continued...

Column Assisted EPS

Column Assisted EPS Systems continue to be the most popular option for manufacturers, this is mainly due to lower cost of making a unit that is protected from the elements inside the vehicles cabin. Another advantage of mounting the EPS System within the cabin is that it does not require any additional space within the engine bay.

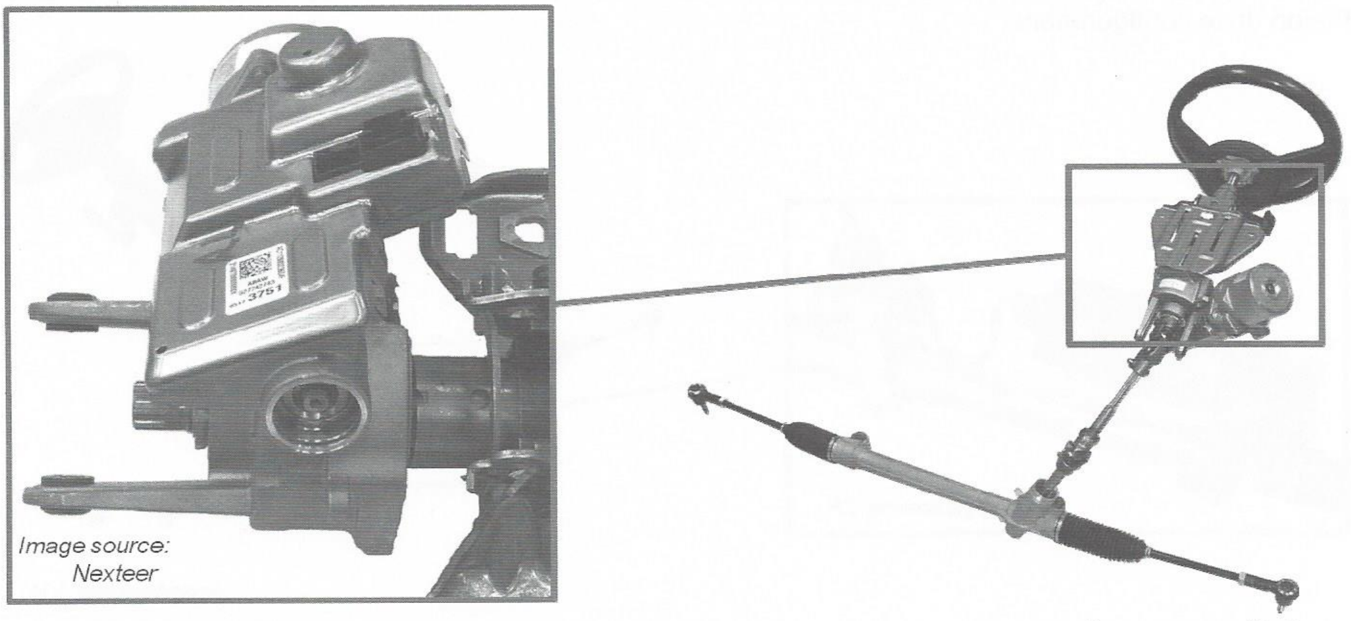


Image source: Nexteer

Image source: Nexteer

Figure 2: Typical Column Assisted EPS System

Pinion Assisted EPS

Pinion Assisted EPS Systems are not dissimilar to that of the Column Assisted configuration, manufactures tend to use this option when the vehicle design provides greater room in the engine bay than behind the dash panel.

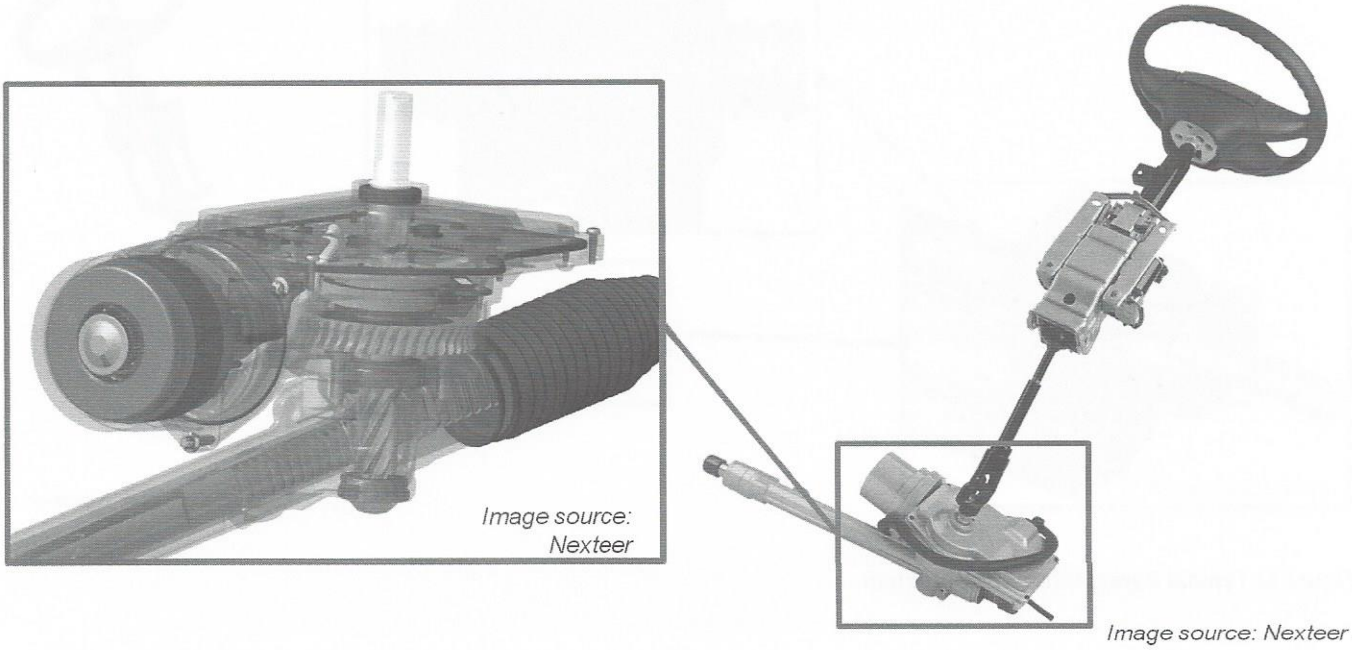


Image source: Nexteer

Image source: Nexteer

Figure 3: Typical Pinion Assisted EPS System

ELECTRONIC POWER STEERING (EPS) continued...

Dual Pinion EPS

Dual Pinion EPS Systems apply the assistance directly to the steering rack. There are two advantages over the Column and Pinion drive configurations:

- Increased strength for larger vehicles
- Reduce electrical load

Dual Pinion EPS Systems typically require about half of the current load when compared to Column and Pinion drive configurations.

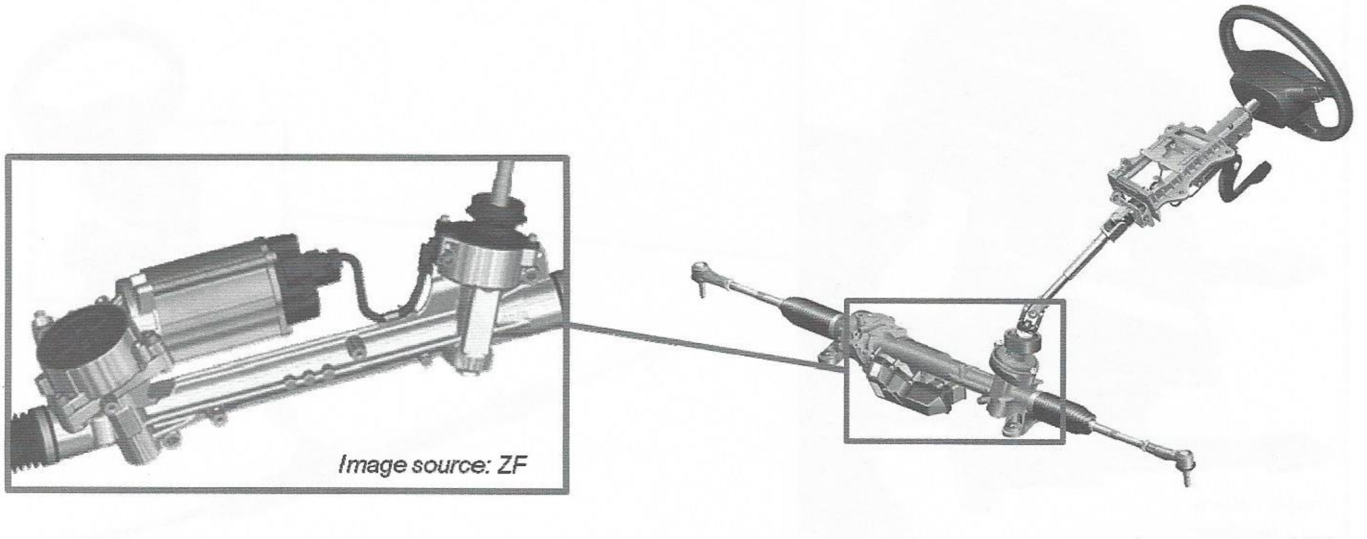


Image source: ZF

Image source: VW

Figure 4: Typical Dual Pinion EPS System

Parallel Drive EPS

Parallel Drive EPS Systems take the advantages of the Dual Pinion EPS configuration a step further. Component manufacturers claim that the belt drive reciprocating ball gearbox used to drive the steering rack is suitable for 4x4 and small truck installations. They also claim to have reduced load on the steering system when an EPS failure occurs.

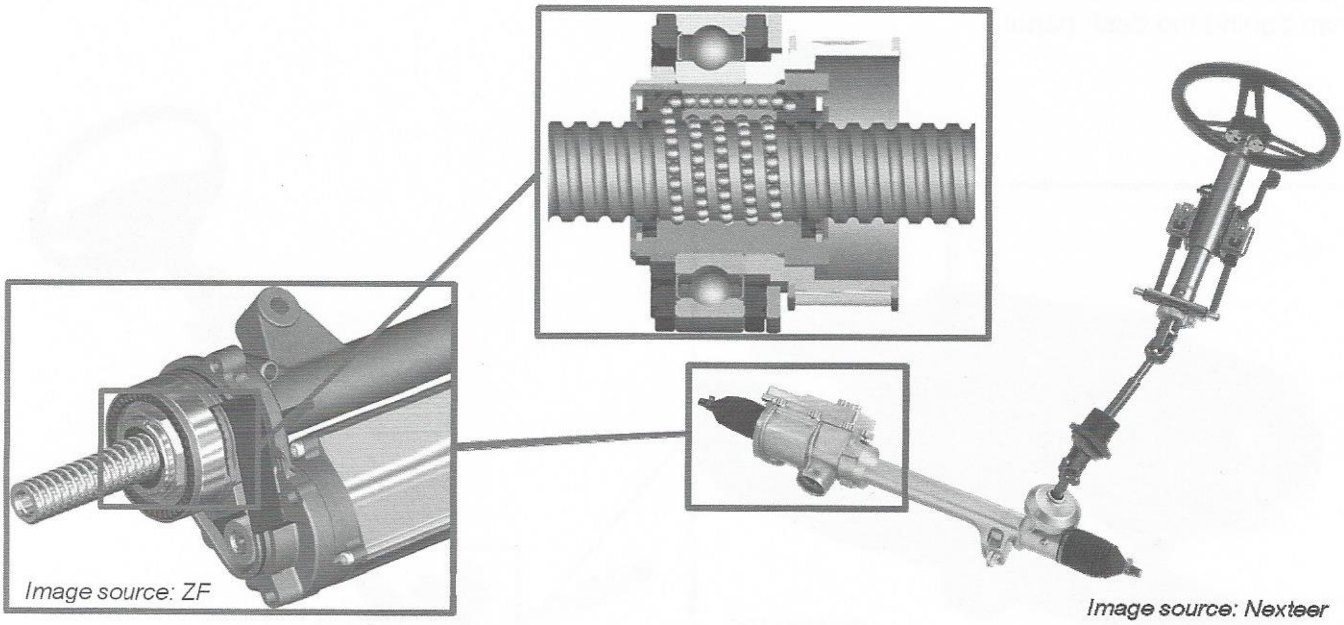


Image source: ZF

Image source: Nexteer

Figure 5: Typical Parallel Drive EPS System

ELECTRONIC POWER STEERING (EPS) continued...

EPS Torsion Bar and Torque Sensor

Torsion Bar

The Torsion Bar is integral to the Torque Sensor. It is situated somewhere on the Steering Column. The mechanical link between the Steering Wheel and the Front Wheels is through the Torsion Bar.
When the turning effort (torque) is applied to the steering wheel by the driver, the resistance of the tyre on the pavement causes the Torsion Bar to bind.

Note: *In the event of an EPS failure the Torsion Bar provides the important mechanical link between the Steering Wheel and the Front Wheels.*

Torque Sensors

The Torque Sensor is connected to either end of the Torsion Bar and measures the amount of deflection along its length. This deflection is used by the EPS Control Module as 'Steering Load'. Based on the Steering Load value the EPS Control Module will provide assistance at the EPS Drive Motor.

There are currently 3 types of Torque Sensors in use:

- Potentiometer
- Photo Diode
- Inductive

Potentiometer

The first generation Toyota Prius (2003-04) was fitted with a Potentiometer type Torque Sensor. The Torque Sensor consisted of two pairs of potentiometers (4 in total) that converted the rotation twist of the torsion bar into an electrical value.

Toyota retired this type of Torque Sensor in 2004 in favour of the contactless inductive type sensor.

Note: *Potentiometers require a contact point, which inevitably leads to wear.*

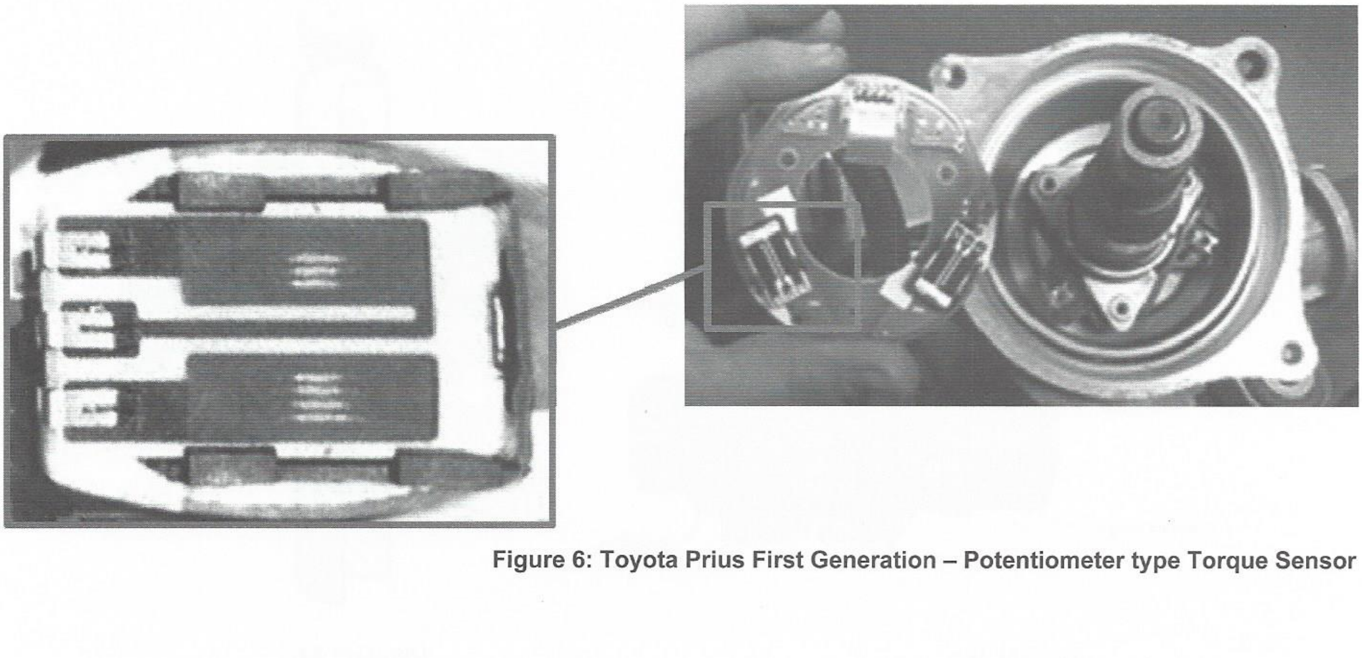


Figure 6: Toyota Prius First Generation – Potentiometer type Torque Sensor

ELECTRONIC POWER STEERING (EPS) continued...

Photo Diode

The photo diode is a contactless sensor that uses two trigger wheels connected to opposite ends of the Torsion Bar. These windows of the pass trigger wheels between the LED and the Receiver. As the alignment between the two trigger wheels varies with torque, the light measured on the receiver is interrupted and the amount of interruption is converted into a waveform and calculated by the EPS Control Module as Torque.

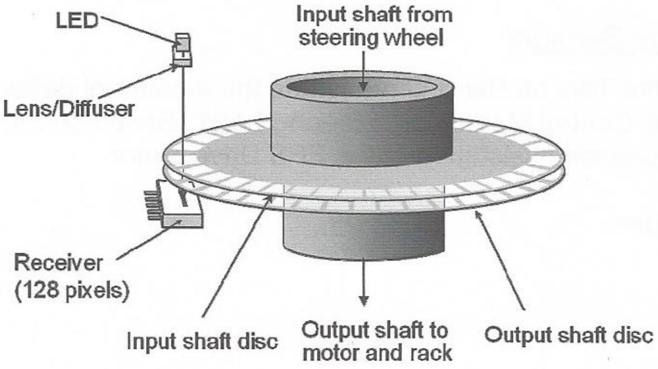

LED
Lens/Diffuser
Input shaft from steering wheel
Receiver (128 pixels)
Input shaft disc
Output shaft to motor and rack
Output shaft disc

Diagram 30:
Photo Diode Torque Sensor (Image source: TRW)

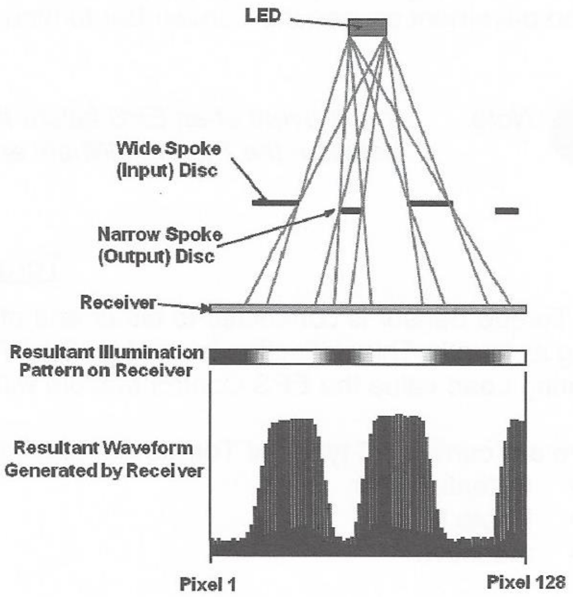

LED
Wide Spoke (Input) Disc
Narrow Spoke (Output) Disc
Receiver
Resultant Illumination Pattern on Receiver
Resultant Waveform Generated by Receiver
Pixel 1
Pixel 128

Diagram 31:
Photo Diode waveform (Image source: TRW)

Inductive

The Inductive type sensor is the 3rd type of Torque Sensor. Both of these examples have dual detection contactless characteristics. The Toyota Prius sensor for 2004 on models has two pickups on separate detection rings, while the VW example has two pickups on a single detection ring. Both of these provide addition back up and diagnostic capabilities not present in the previous examples.

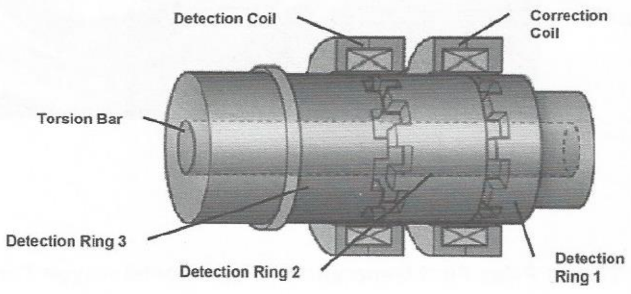

Detection Coil
Correction Coil
Torsion Bar
Detection Ring 3
Detection Ring 2
Detection Ring 1

Diagram 32:
Inductive Torque Sensor (Image source: Toyota)

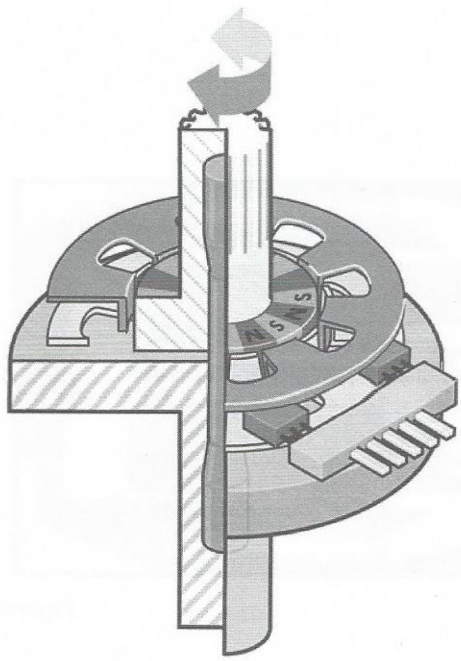


Diagram 33:
Inductive Torque Sensor (Image source: VW)

ELECTRONIC POWER STEERING (EPS) continued...

EPS Control Module

The EPS Control Module is directly responsible for the control of the EPS System. It relies on CAN-BUS for critical information including:

- Vehicle Speed (VSC Module)
- Ready Signal (Hybrid Drive ECU)
- Warning Lights (Cluster ECU)
- Warning Message (Display ECU)

The EPS Control Module uses the information from its sensors and the CAN BUS Network to accurately detect the amount of steering assistance in any conditions.

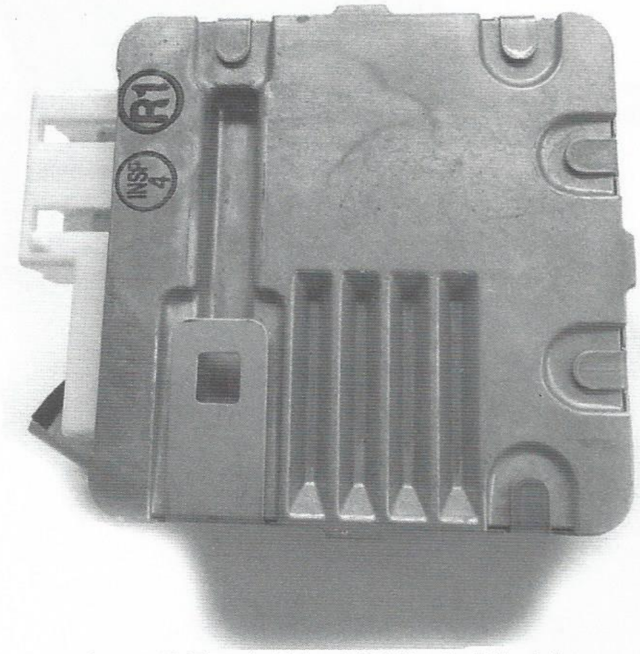


Image 7: Toyota Prius EPS Control Module Top View

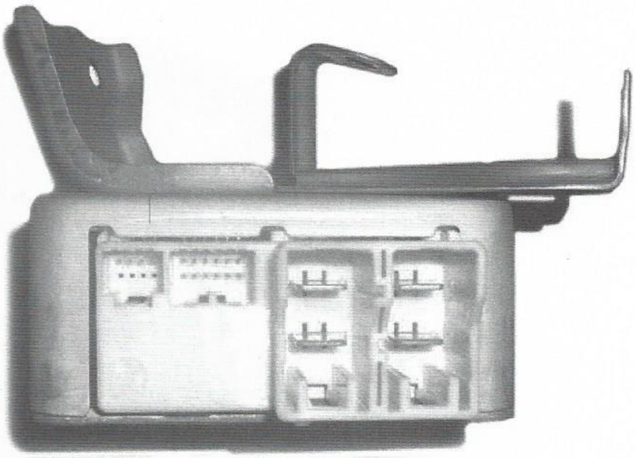


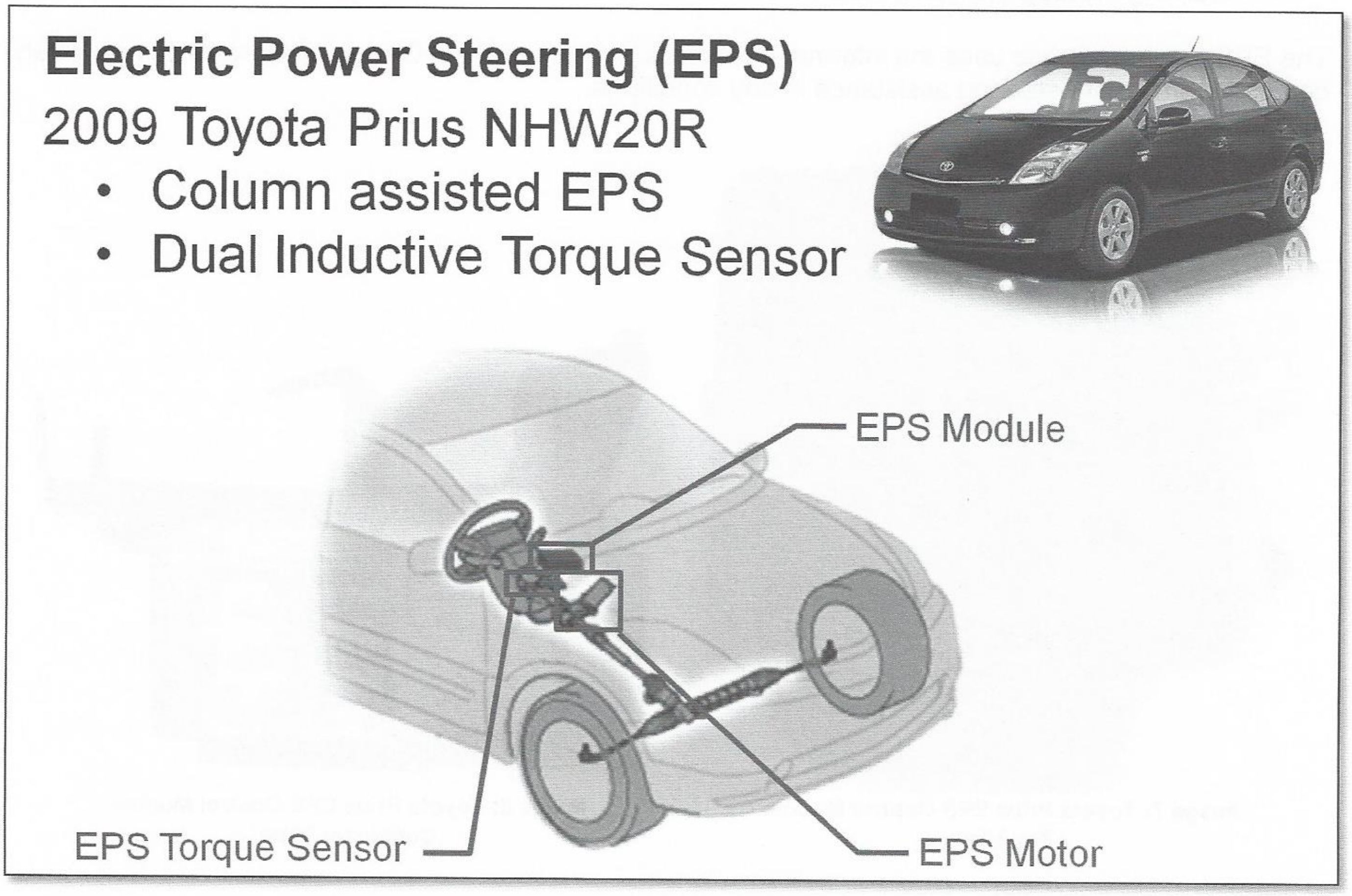
Image 8: Toyota Prius EPS Control Module Connector View

ELECTRONIC POWER STEERING (EPS) continued...

EPS Current Draw Inspections

Any seized or worn components in the mechanical system or within the EPS Motor will cause in increase in the current draw required to turn the wheels from lock to lock. The following tests were carried out on vehicles in an 'as new' serviceable condition. As you follow through the inspection page by page you will also see how the configuration of the EPS System affects its electrical load.

Toyota Prius



Electric Power Steering (EPS)

2009 Toyota Prius NHW20R

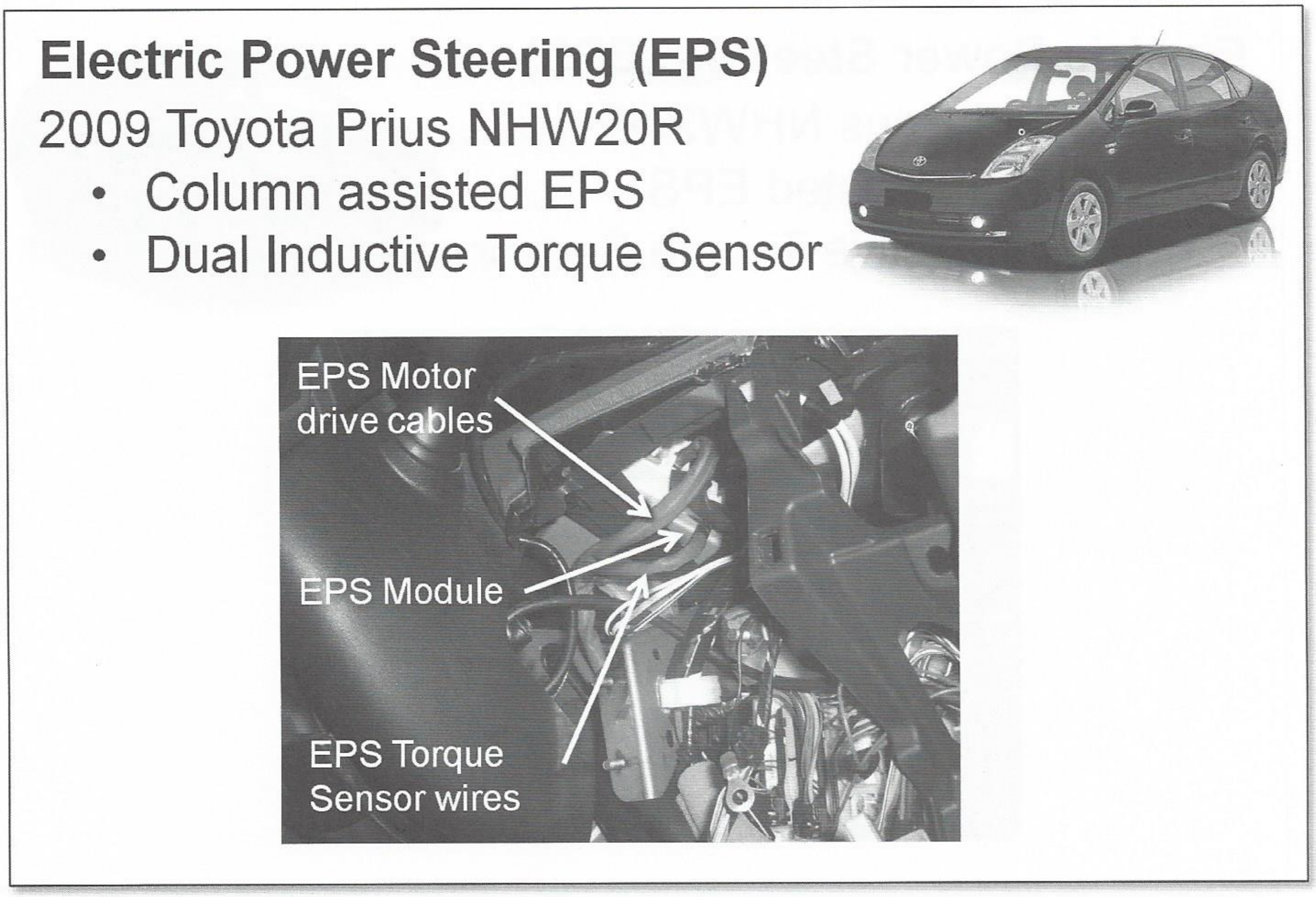
- Column assisted EPS
- Dual Inductive Torque Sensor

EPS Module

EPS Torque Sensor

EPS Motor

ELECTRONIC POWER STEERING (EPS) continued...



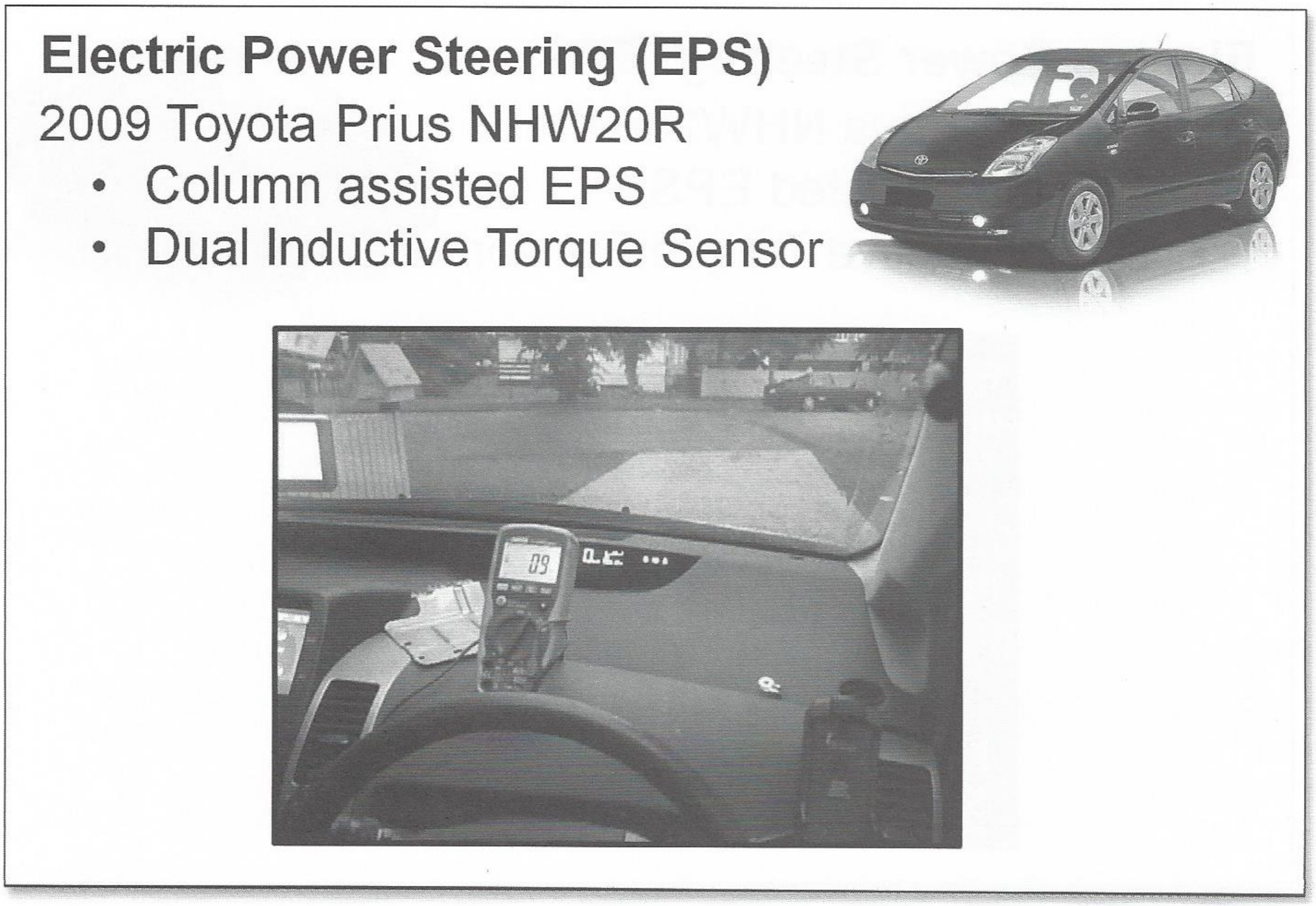
Electric Power Steering (EPS)

2009 Toyota Prius NHW20R

- Column assisted EPS
- Dual Inductive Torque Sensor

EPS Motor drive cables
EPS Module
EPS Torque Sensor wires

ELECTRONIC POWER STEERING (EPS) continued...



Electric Power Steering (EPS)

2009 Toyota Prius NHW20R

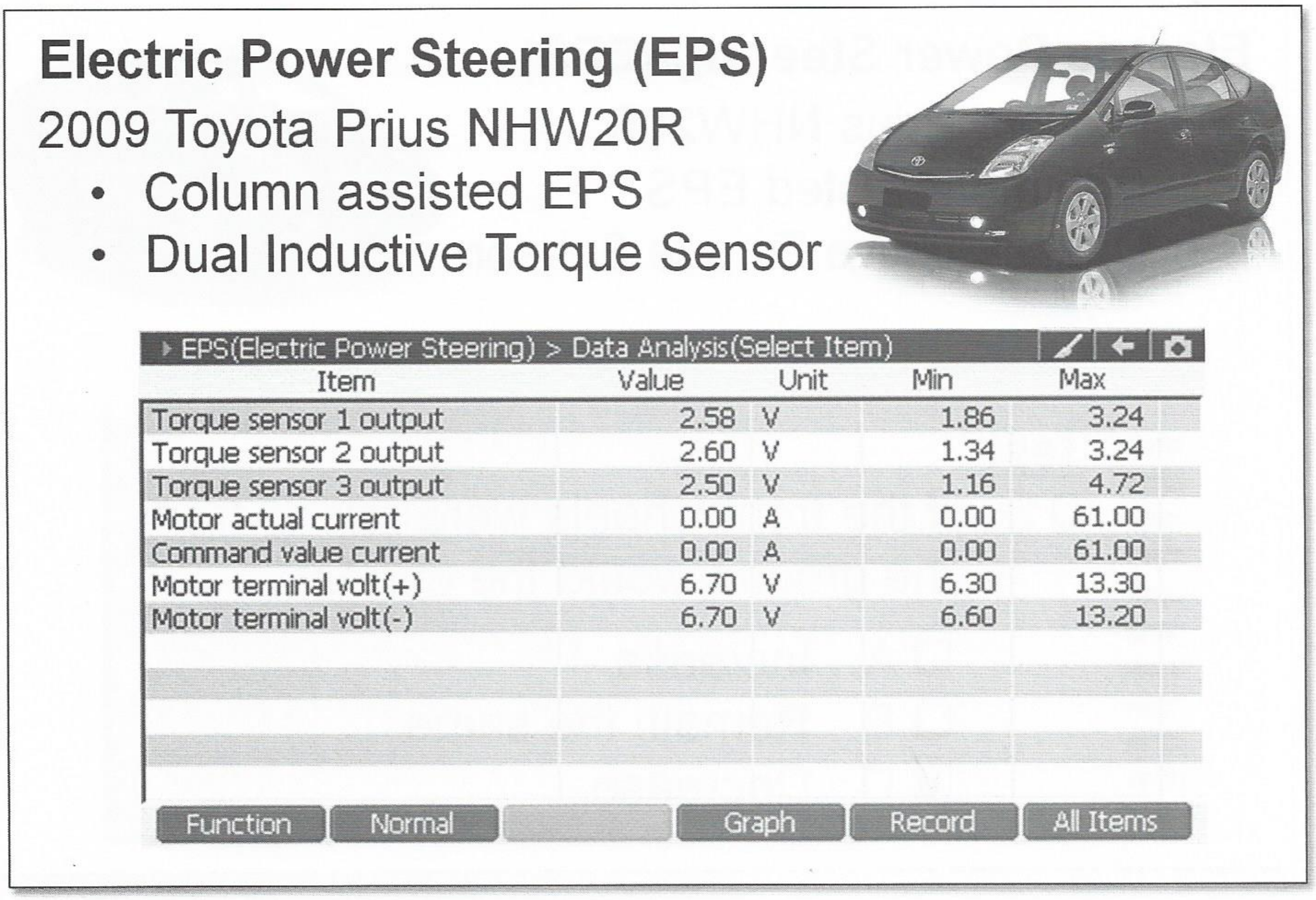
- Column assisted EPS
- Dual Inductive Torque Sensor

Q: In the video that was played on the screen,

What was the peak amperage reading? ....

When did the EPS Motor reach peak amperage? . FULL LOCK

ELECTRONIC POWER STEERING (EPS) continued...



Electric Power Steering (EPS)

2009 Toyota Prius NHW20R

- Column assisted EPS
- Dual Inductive Torque Sensor

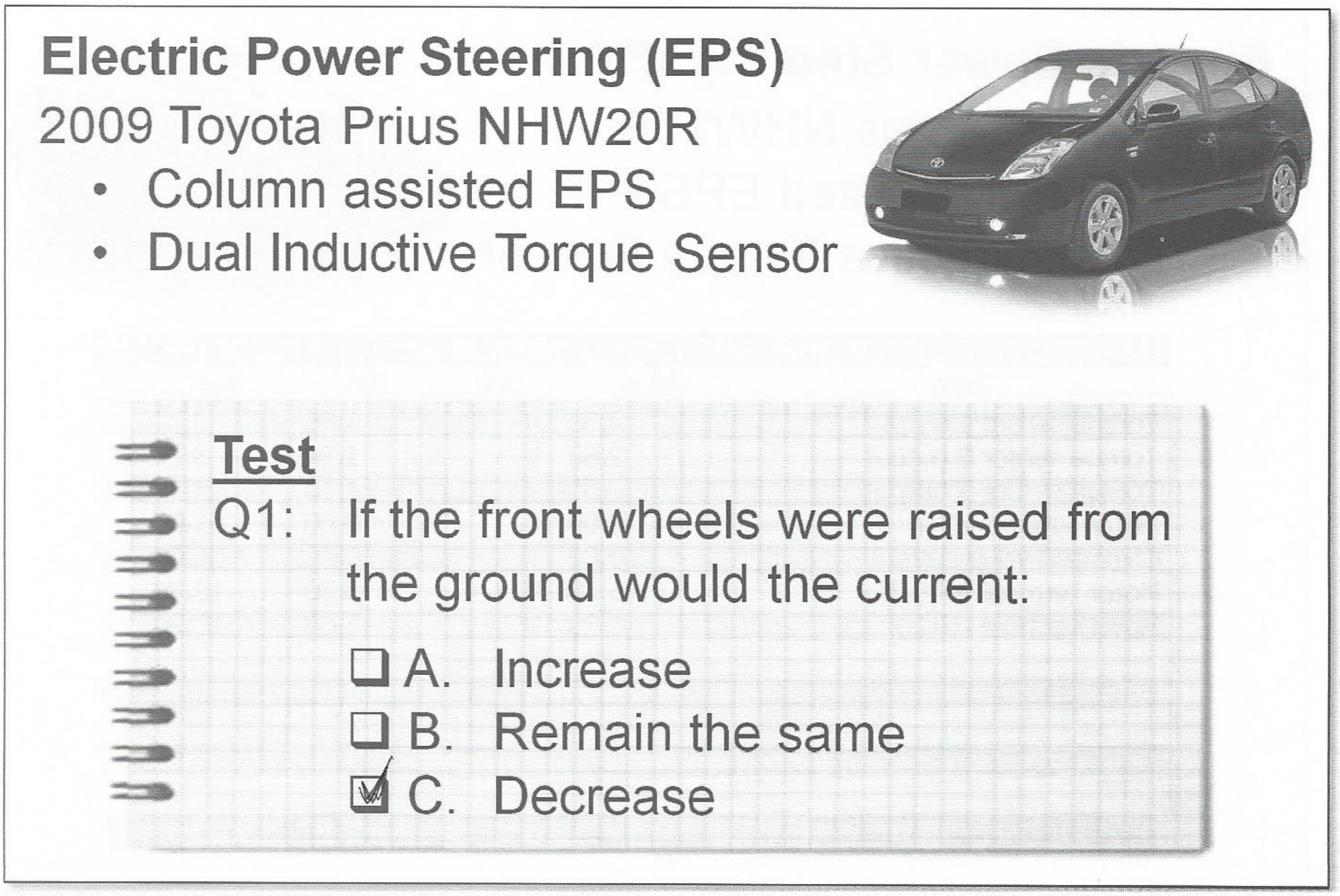
▸ EPS(Electric Power Steering) > Data Analysis(Select Item)

Item	Value	Unit	Min	Max
Torque sensor 1 output	2.58	V	1.86	3.24
Torque sensor 2 output	2.60	V	1.34	3.24
Torque sensor 3 output	2.50	V	1.16	4.72
Motor actual current	0.00	A	0.00	61.00
Command value current	0.00	A	0.00	61.00
Motor terminal volt(+)	6.70	V	6.30	13.30
Motor terminal volt(-)	6.70	V	6.60	13.20

Q: On the previous page you noted the peak amperage,

Was it similar to the value recorded here by the Scan Tool? . ...

ELECTRONIC POWER STEERING (EPS) continued...



Electric Power Steering (EPS)

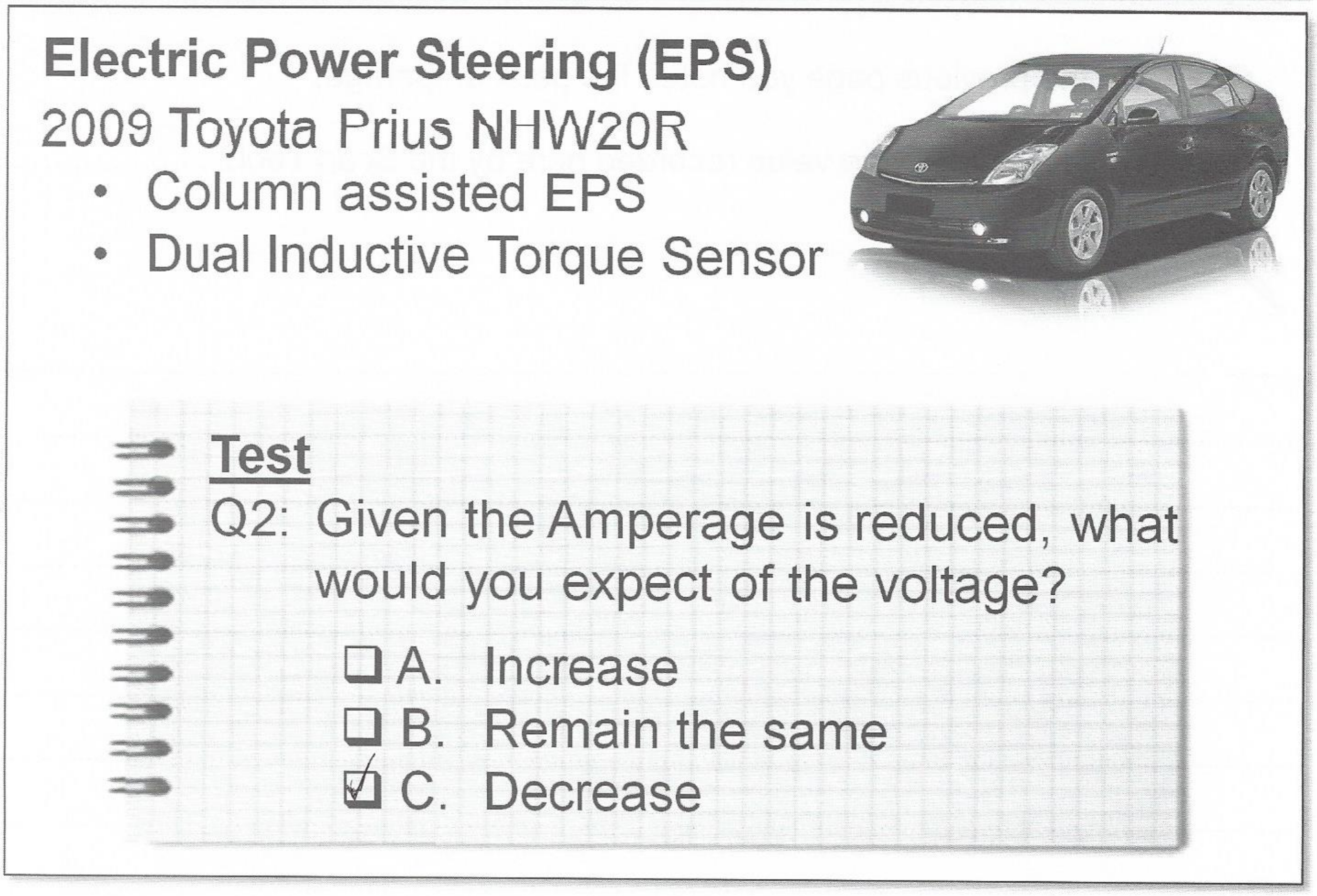
2009 Toyota Prius NHW20R

- Column assisted EPS
- Dual Inductive Torque Sensor

Test

Q1: If the front wheels were raised from the ground would the current:

☐ A. Increase
☐ B. Remain the same
☑ C. Decrease



Electric Power Steering (EPS)

2009 Toyota Prius NHW20R

- Column assisted EPS
- Dual Inductive Torque Sensor

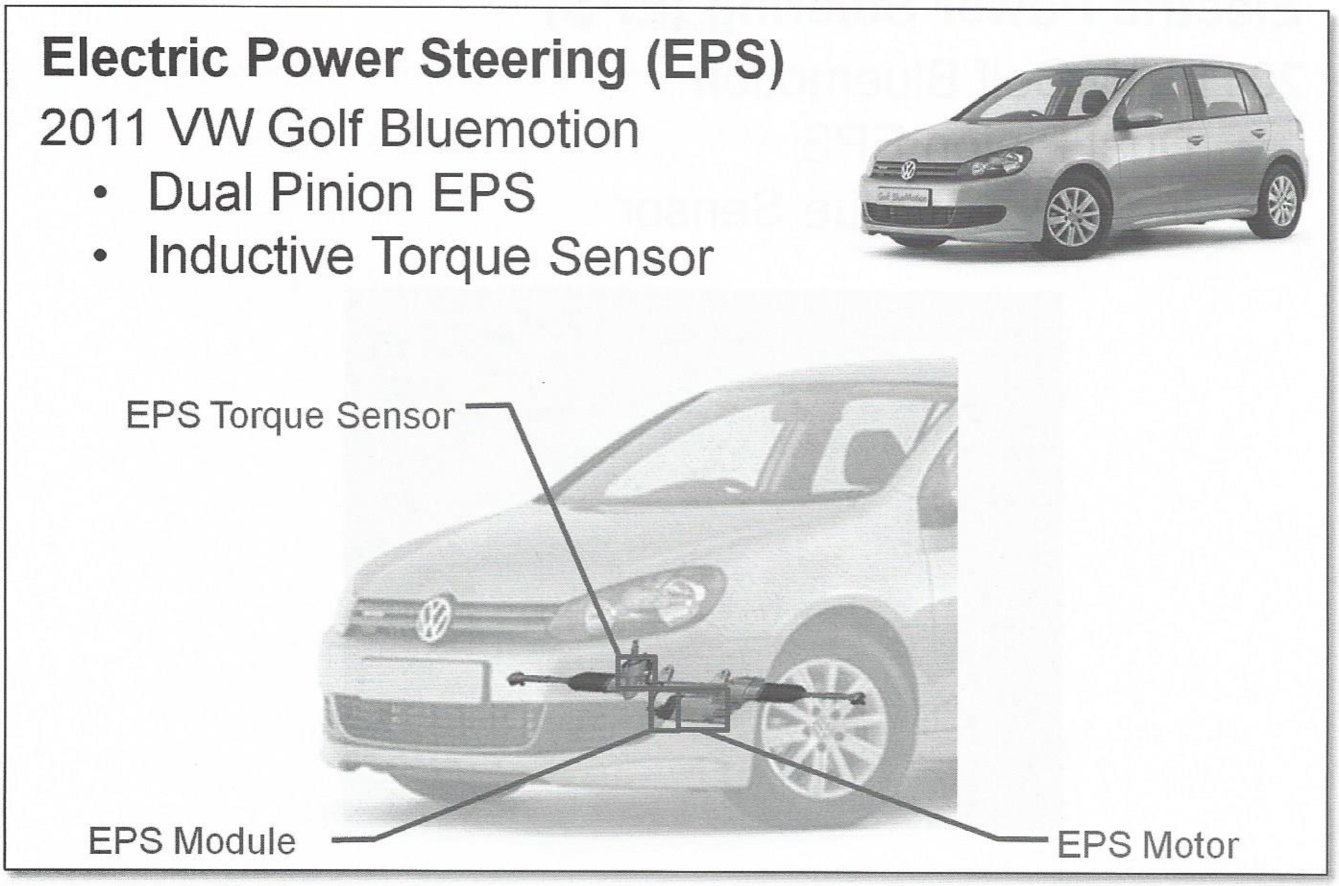
Test

Q2: Given the Amperage is reduced, what would you expect of the voltage?

☐ A. Increase
☐ B. Remain the same
☑ C. Decrease

ELECTRONIC POWER STEERING (EPS) continued...

Volkswagen Golf



Electric Power Steering (EPS)

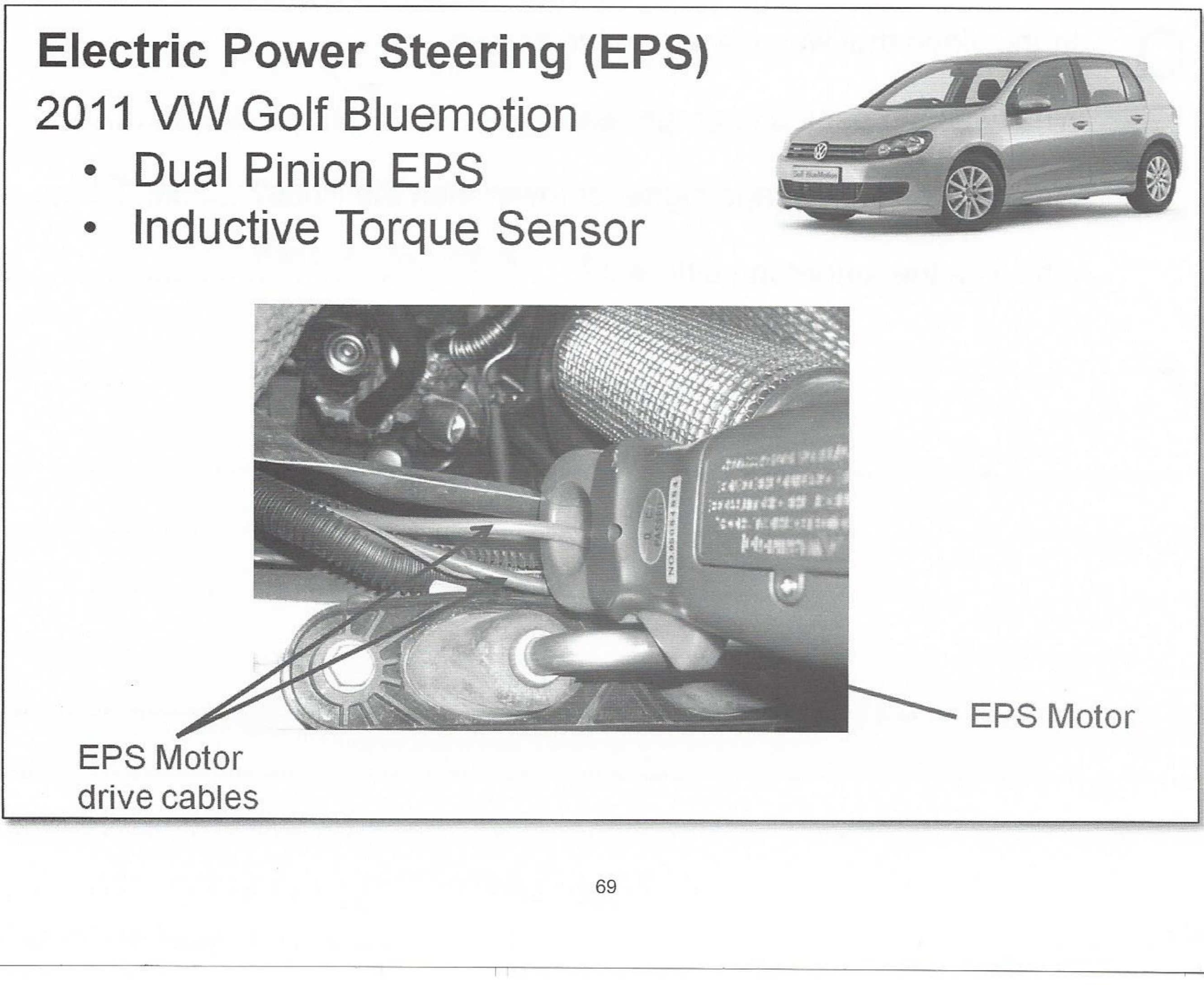
2011 VW Golf Bluemotion

- Dual Pinion EPS
- Inductive Torque Sensor

EPS Torque Sensor

EPS Module

EPS Motor



Electric Power Steering (EPS)

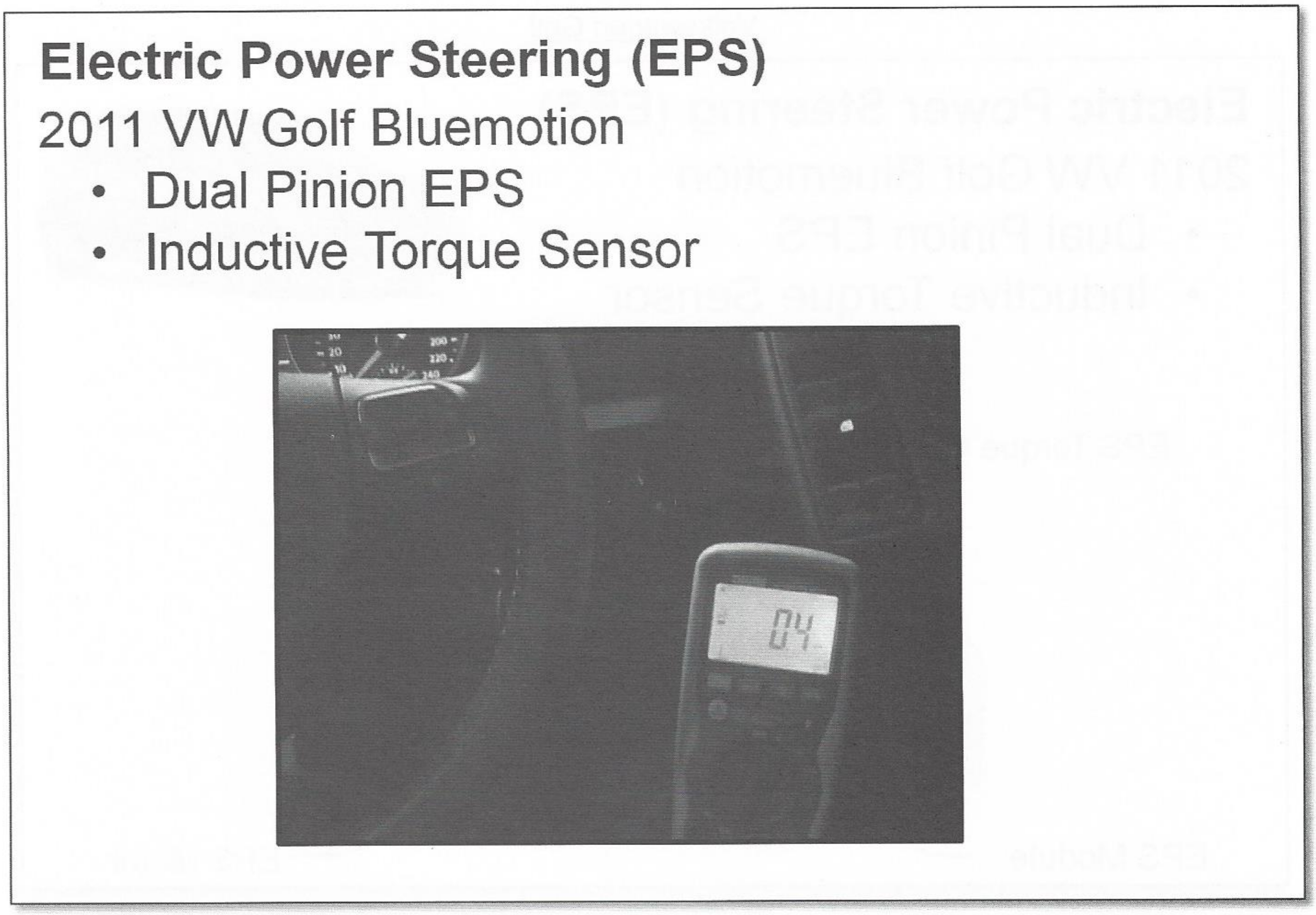
2011 VW Golf Bluemotion

- Dual Pinion EPS
- Inductive Torque Sensor

EPS Motor

EPS Motor drive cables

ELECTRONIC POWER STEERING (EPS) continued...



Electric Power Steering (EPS)

2011 VW Golf Bluemotion

- Dual Pinion EPS
- Inductive Torque Sensor

Q: In the video that was played on the screen,

What was the peak amperage reading? 26

Was the peak amperage higher or lower than the Prius? Lower

Why was the amperage different? DIFFERENT SYSTEM

ELECTRONIC PARKING BRAKE (EPB)

Electronic Parking Brakes started to appear in European vehicles at the turn of this century, their introduction is based mainly on safety and ease of use.

Benefits of EPB's include:

- High brake force from minimal operator effort
- No bulky lever or pedal
- Electronic movement monitoring (failsafe)
- Driveability features such as hill-holding
- Auto stopping features for high traffic conditions
- Auto parking systems

There are to EPB configurations:

- Cable Actuated
- Electronic Brake Calliper

Cable Actuated

Cable Actuate EPB's where the first electronic parking systems to be introduced and provide a number of advantages as shown in the list above.
The Actuator (see *Image 9*) is located either under the car or inside the boot. The Actuator consists of a Motor, Drive and Tension Sensor (and in some cases the control module is also integrated into the Actuator). When the EPB is activated the motor applies load to the cables to actuate the parking brakes. The load (tension) sensor monitors the amount of force applied by the motor and the EPB Control Module will stop the motor when the predetermined load is applied.

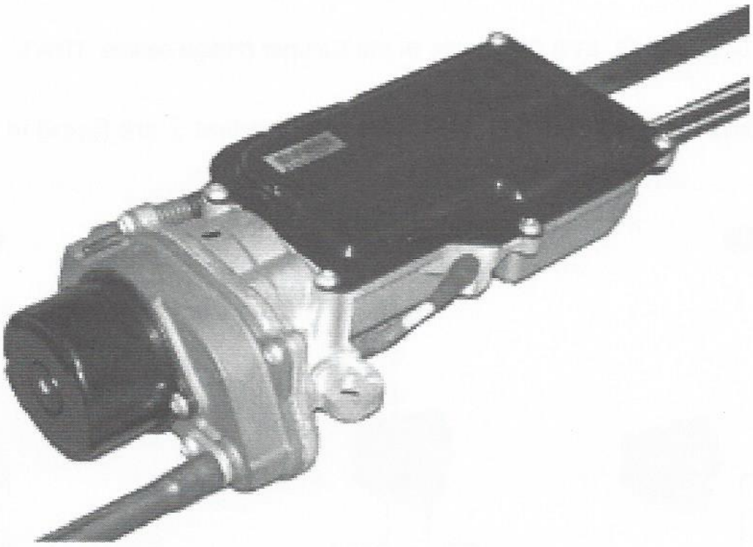


Image 9: Lexus EPB Actuator

Like its manually operate cousin, the Cable Actuated EPB relies heavily on the correct adjusting procedure and there are usually at least 3 factors to consider.

1. Setting the Control Module/Actuator into adjustment mode
2. Adjustment of the Park Brake Shoes within the rear disc assembly (hat)
3. Adjustment of the cables (sometimes there are cable adjustments either side of the Actuator)

ELECTRONIC PARKING BRAKE (EPB) continued...

Electronic Brake Calliper

The use of Electronic Brake Callipers in EPB systems simplifies the mechanical construction as it simply uses the disc brakes for parking brake operation.

Benefits over and above those listed for the cable actuated systems include:

- Actuator motor integrated into calliper
- Load applied directly to calliper piston
- Self adjusting
- Improved safety integration

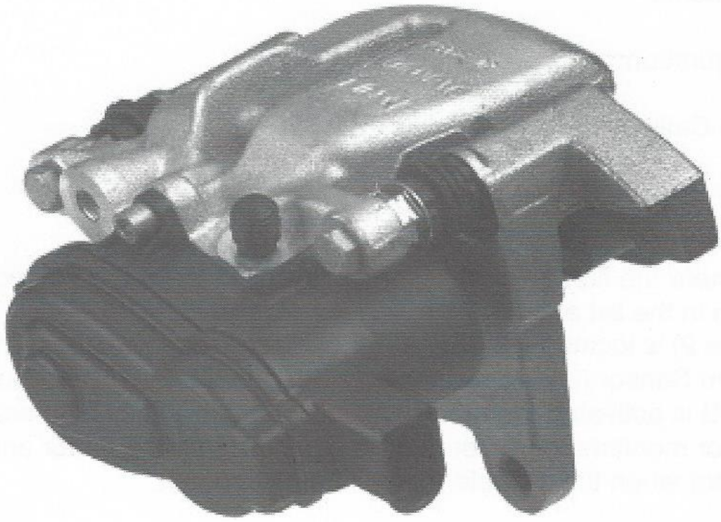


Image 10: EPB Electronic Brake Calliper (Image source: TRW)

There are 3 configurations for EPB Systems although only the first 2 are found in the Australian market:

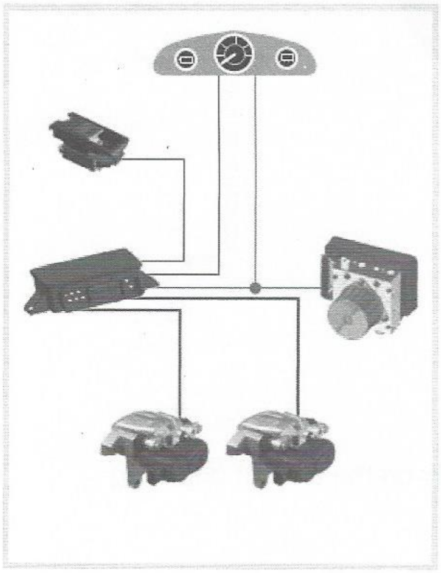


Diagram 34:
Typical EPB System
(Image source: TRW)

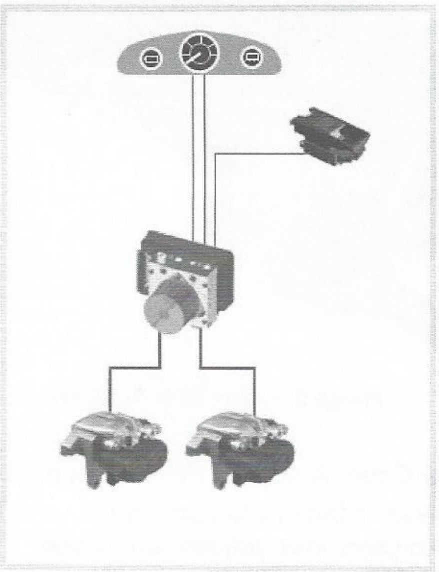


Diagram 35:
Integrated into ESP
(Image source: TRW)

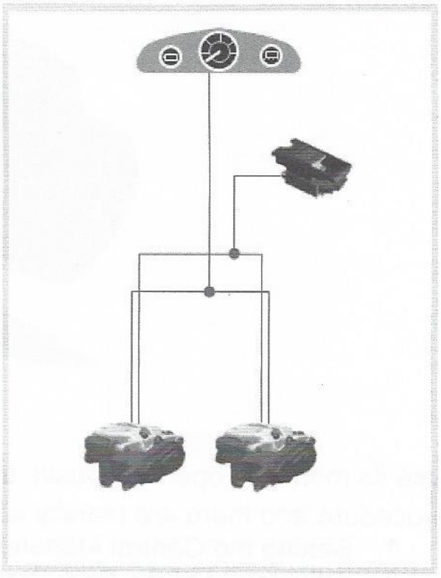


Diagram 36:
Incorporated into Calliper
(Image source: TRW)

ELECTRONIC PARKING BRAKE (EPB) continued...

The construction of an EPB calliper is illustrated in *Figure 7*, it is essentially a standard hydraulic calliper with the addition of the following components:

- Motor and reduction gear assembly mounted to the backside of the calliper
- Worm drive piston actuator on the inside of the calliper piston (shown in black)

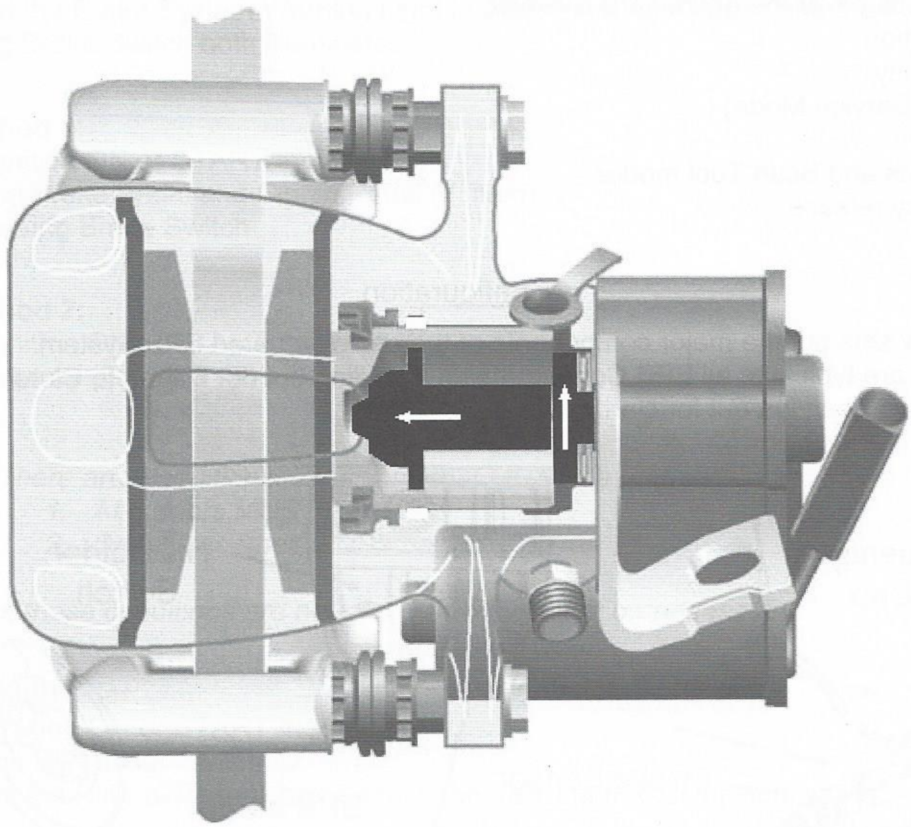


Figure 7: EPB Electronic Brake Calliper – Sectioned view (Image source: VW)

Typical procedure for Brake Pad replacement with Electronic Brake Callipers:

1. Connect a compatible Scan Tool
2. Command the EPB Motor to the home position
3. Remove callipers
4. Open the bleed screw
5. Push pistons back with the typical brake piston return tool
6. Close off the bleed screw
7. Refit Brakes
8. The final stage is done on the Scan Tool, this stage is very model specific and can include:
    - Initialisation
    - Bedding in
    - Electronic Adjustment

Caution: *The procedure described above is of a typical nature and is design to illustrate the steps involved.*

Ensure that the specific manufacturer's procedure is followed!

ELECTRONIC PARKING BRAKE (EPB) continued...

Isolation (Service Mode)

Unlike some manufacturers the Subaru Outback does have or require an Isolation/Service Mode.

Auto-Tech recommends:

- Ensuring the Hill Holder feature is OFF before commencing
- Remove the keys from the Ignition
- Disconnecting the Battery for absolute certainty

Caution: ALWAYS follow specific manufactures instructions when isolating electronic functions such as EPB's.

Adjustment

The Parking Brake Shoes can be adjusted via the inspection hole in the rear Brake Discs.

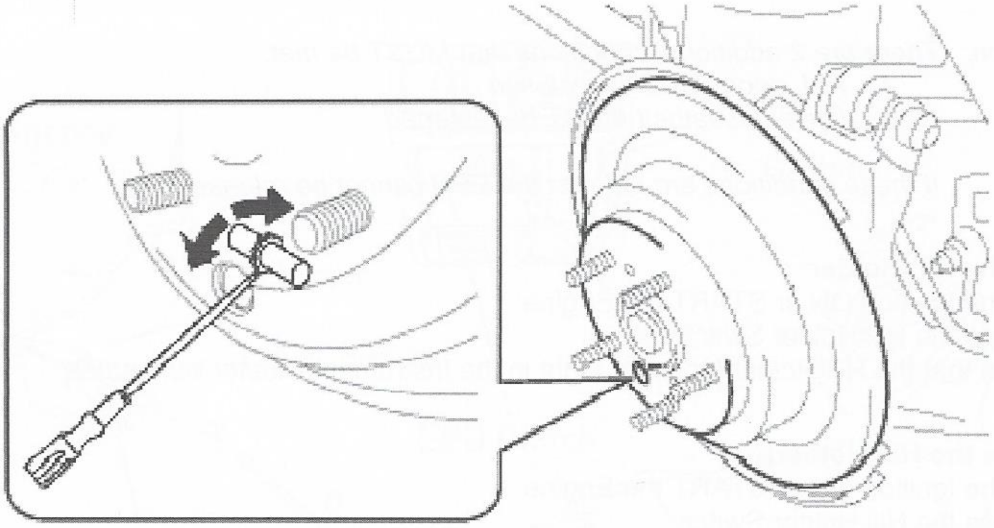


Diagram 38: Outback EPB shoe adjustment (Image source: Subaru)

Note: The Outback does not require any manual adjustment of the EPB Cables.

ELECTRONIC PARKING BRAKE (EPB) continued...

Calibrations and Scan Tool modes

Using a capable Scan Tool the following calibrations are used to set and adjust the EPB System:

- Parking Brake Dismantle Mode
- Brake Shoe Bedding-in Mode
- Force Sensor Calibration Mode
- Clutch Sensor Calibration Mode
- Clutch Engagement Position Mode
- Parameter Initialisation Mode

Parking Brake Dismantle Mode

This feature winds out the cable to assist in Parking Brake Shoe and Cable removal

Brake Shoe Bedding-in Mode

Used to bed-in new Parking Brake Shoe Linings

Force Sensor Calibration Mode

Used by the EPB Control Module to adjust the Cables

Clutch Sensor Calibration Mode

This procedure programs the extreme positions of the Clutch travel.

Clutch Engagement Position Mode

The previous Clutch Sensor Calibration procedure sets basic parameters. However, the varying characteristic that set the clutch take-up point are not catered for.

The Clutch Engagement Position procedure is used to tell the EPB Control Module the exact point at which drive is transferred tho the rear wheels.

1. Set approximate position on a road test
2. Adjust the position manually with a Scan Tool, this allows the point set in step 1 to be adjusted by 50 to 80%.

Parameter Initialisation Mode

This feature is used to initialise a new EPB Control Module.

ELECTRONIC PARKING BRAKE (EPB) continued...

Emergency Release

In the event that the Parking Brake cannot be released (e.g. Flat Battery with EPB on), the Actuator can be wound off to release the cables and in turn the Parking Brake Shoes.

To release the EPB:

1. Engine OFF, Trans in "P" (1st for M/T)
2. Chock Wheels
3. Retrieve tool from Kit
4. Turn the Actuator Dust Cap anti-clockwise to remove (see *Diagram 39*)
5. Insert tool and rotate clockwise 225±25 turns (see *Diagram 40*)
6. Replace the Actuator Dust Cap.

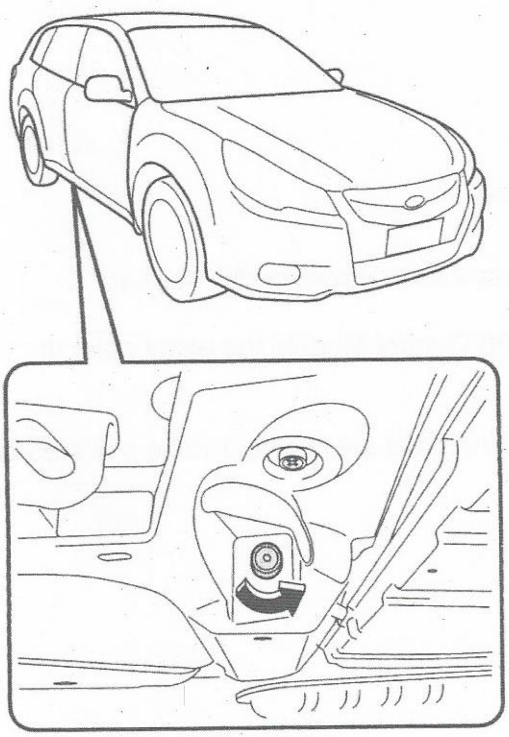


Diagram 39:
Outback EPB Emergency Release
(Image source: Subaru)

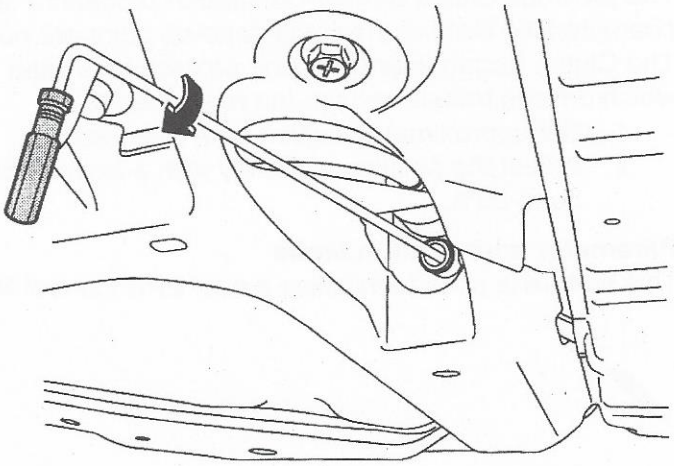


Diagram 40:
Outback EPB Emergency Release
(Image source: Subaru)